AD623087

DC-FR-1041

DEVELOPMENT OF "TYPICAL" URBAN AREAS AND ASSOCIATED CASUALTY CURVES

L. Wayne Davis
Francis J. Wall
Donald L. Summers

Final Report
on
Contract No. OCD-PS-64-47

Prepared for

OFFICE OF CIVIL DEFENSE
OFFICE OF THE SECRETARY OF THE ARMY
DEPARTMENT OF THE ARMY
WASHINGTON, D. C.

April, 1965

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THE Dikewood CORPORATION
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ACKNOWLEDGMENT

The authors wish to express their gratitude for the support offered by Mr. John F. Devaney and Mr. Robert Whitney of the Office of Civil Defense and by Mr. R. B. Bothun, Civil Defense Technical Office, of the Stanford Research Institute, particularly in regard to their suggestions concerning the presentation of the final report. Gratitude is also expressed to Mrs. Helen Tuttle for the excellent job of guiding and supervising the reading of the Sanborn maps.

ABSTRACT

The development of "typical" urban areas (determined by the land use and the types of building construction) and the associated casualty curves is the subject of this contractual effort. The primary source for information concerning building construction throughout the United States is the Sanborn maps. Specific types of areas within selected cities were chosen for detailed study. Whenever possible, samples were included of downtown business areas, manufacturing areas, commercial (wholesale and warehouse) areas, and various residential areas. A block-by-block, building-by-building survey of information from the Sanborn maps was conducted. Occupancy, block area, total floor area, height, number of floors, construction details, etc. were recorded for each building in the block being surveyed. These data were punched on IBM cards, verified, and put on magnetic tape. Computer summaries were then made of these data.

From these summaries statistical analyses were made to detect whether any differences in construction occurred for given land uses due to (1) geographic region and (2) urban area size. From these results lists of typical urban areas were developed.

From these basic data it was then possible to draw total mortality and total injury curves for an unwarned population (daytime) for each of the ten typical urban areas. These curves are presented for surface and the Hiroshima scaled height of burst (846 feet) and for yields of 0.4, 1, 4, 10, 25, and 50 Mt. Capability is also provided for estimating casualties in a nighttime and a warned configuration.

With this set of casualty curves classified by typical urban area and with land-use maps for the various cities of interest across the country, one is in a position to make both a practical and realistic casualty assessment on a national scale.

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CHAPTER I

INTRODUCTION AND SUMMARY

An extensive set of casualty curves categorized by shielding type or building construction was developed by Dikewood under Contract No. OCD-OS-62-203. Quite an accurate casualty assessment could be made on the basis of such curves. However, there is one primary drawback for a national casualty assessment program; the details would be too voluminous to be practical. Thus, one must enlarge the basic unit from building-by-building casualty curves to area-by-area casualty curves. The development of the "typical" areas, determined by the land use and the types of building construction, is the subject of this contractual effort.

The diversity of urban areas in the United States is so large that the description of one typical area is impossible. Even when the general urban land use such as residential, commercial, etc. is specified, the diversity still remaining precludes any precise description of one typical area for each. However, by assigning several typical areas (to be determined during this study) to each general urban land use, the probability of being able to represent accurately any particular urban area is much higher. This work involved the study of urban areas in general and a description of specific area types in terms of building construction.

The primary source for information concerning building construction and use throughout the United States is the Sanborn maps (drawn to scale),

utilized primarily by the fire-insurance underwriters. Specific types of areas within selected cities were chosen for detailed study. Whenever possible, samples were included of downtown business areas, manufacturing areas, commercial (wholesale and warehouse) areas, and various residential areas such as apartment-house, multi-family, and single-family dwellings. A block-by-block, building-by-building survey of information from the Sanborn maps was conducted. Occupancy, block area, total floor area, height, number of floors, construction details, etc. were recorded for each building in the block being surveyed. These data were punched on IBM cards, verified, and put on magnetic tape by means of error-checking routines. Summaries* were then made of these data utilizing Dikewood's IBM-7044 computer.

From these summaries statistical analyses were made to detect whether any differences in construction occurred for given land uses due to (1) geographic region and (2) urban area size. From these results lists of typical urban areas were developed and are presented in Tables 42, 44, and 47 for different conditions.

From these basic data it was then possible to draw total mortality and total injury curves for an unwarned population (daytime) for each of the ten typical urban areas given in Table 47. These curves are presented

* Working summaries were developed giving listings by city block, Sanborn volume, urban area, urban-area size, geographic region, and the United States.

in Figs. 24 through 59 of Chapter VIII for surface and the Hiroshima scaled height of burst (846 feet) and for yields of 0.4, 1, 4, 10, 25, and 50 Mt. Capability is also provided for estimating casualties in a night-time and a warned configuration.

With this set of casualty curves classified by typical urban area and with land-use maps for the various cities of interest across the country, one is in a position to make both a practical and realistic casualty assessment on a national scale.

CHAPTER II

SELECTION OF URBAN AREAS

A. INTRODUCTION

This chapter describes the selection of the urban areas to be sampled during the study in order to obtain a nationwide description of urban building construction and use. While it is possible to list some of the factors that influence urban building construction and use, many other factors will be poorly understood at best and may be limited to only vague ideas. To improve the sampling process, the population of urban buildings from which the sample is to be chosen can be divided, or stratified, according to the factors influencing the composition of the population. Then from each strata a small random sample can be chosen and combined for the required sample of urban areas.

During initial considerations, a number of factors were considered for stratification. Among these factors were the following items:

Temperature: average maximum for January
average maximum for July
average minimum for January
average minimum for July

Humidity: average for maximum month
average for minimum month

Rainfall: average for maximum month
average for minimum month

Altitude

Proximity to natural building material

Economic conditions

Geographic-climatic region

Size of the urban population

Age of urban area: may be highly correlated with area size, and

Density of the urban population.

While it may appear desirable to stratify on all known and seemingly important factors, practical sampling considerations prevent the effective use of more than two or three of the most important ones. In fact, if one considers the representative list above, it is obvious that a geographic-climatic classification will include most of the factors which might influence building construction. Therefore, for this study two characteristics of the urban areas in the United States were chosen for stratification purposes. These were (1) the geographic-climatic region and (2) the size of the urban population. A brief discussion and justification of these variables are given below.

In addition to the geographic-climatic region and urban population, two other secondary factors were chosen for broad and uniform representation in the final sample. These were (1) the density of the urban population and (2) the average temperatures experienced in the contiguous United States. A brief discussion of the importance of these variables is also given below.

Finally, if the four factors noted above seemed equal for two or more urban areas, the choice was made on the basis of target information as contained in The Probable Fallout Threat over the Continental United States (Ref. 1).

The geographic-climatic region determines the type of construction required. For example, the colder regions such as the Dakotas and Minnesota require a type of construction differing considerably from that required along the Gulf Coast. The geographic-climatic region also influences the variety and kinds of building materials available for local use. As an example, the dry Southwest uses adobe quite extensively while the southeastern states use much native yellow pine.

Depending on the definition, about 215 localities in the United States had a population above 50,000 in 1960. The largest of these (New York and northeastern New Jersey) had a population of over 14,000,000. The height of office buildings in the central business districts should also be directly related to the urban population. As an example, buildings with more than twenty floors are seldom found in a city of less than 500,000 inhabitants while most larger cities have buildings of this height.

The population density of central cities varies from over 24,000 per square mile on Manhattan Island (New York) to 400 per square mile in a city of Maine. The height of residential buildings should also be directly related to the population density. As an example, it is impossible to house 24,000

per square mile in single-family dwellings; likewise, it is impossible to utilize multifloored apartment buildings in cities with densities of only 400 per square mile.

Finally, a wide range of temperatures (particularly within each geographic-climatic region) will assure better representation of the type of construction required and of the materials that are locally available.

The survey effort assigned to each urbanized area must be subdivided by land-use areas. Since the resulting summaries may be used to describe all cities in the contiguous United States, the survey effort must also be proportioned according to the population to be represented. For example, since about 66 percent of the urban population lives east of the Mississippi River, then about 66 percent of the survey effort should be in that area. Similarly, since about 54 percent of the urban population lives in cities larger than 500,000, then about 54 percent of the survey effort should be in urban areas of that size. Such an allocation is necessary to minimize errors in the use of the sample summaries representing U. S. cities.

B. GEOGRAPHIC-CLIMATIC REGIONS

Building size and construction varies widely throughout the contiguous United States. By dividing the United States into smaller geographic regions, summaries of building size and construction will better represent local conditions and needs and hence be more homogeneous within any one area than for the country as a whole. Any division of the states into small groups will be somewhat arbitrary and probably based unconsciously on

traditional state groupings. However, there are four principles that must guide the selection of the geographic-climatic regions for this study. These are as follows:

(1) The states should be contiguous;

(2) They may have something in common, such as a shore line;

(3) They should have some basic climatic similarities; and

(4) They should have some basic economic similarities.

The Bureau of the Census has established geographic divisions of the states for purposes of the population census. These divisions are shown in Fig. 1. Since some of these divisions exhibit the characteristics considered desirable for this study, this set is taken as a point of departure. Moving from right to left in Fig. 1, the first division that might exhibit too much diversity in building construction is the South Atlantic. To forestall this possibility, the South-Atlantic division was subdivided into two divisions as shown in Fig. 2.

Other divisions that might exhibit too much diversity in building construction are the Mountain and Pacific divisions. To forestall this possibility and to create divisions with more of the characteristics considered desirable for this study, these two divisions were combined and then redivided into three divisions as shown in Fig. 2.

FIG. 1

CENSUS GEOGRAPHIC DIVISION OF UNITED STATES

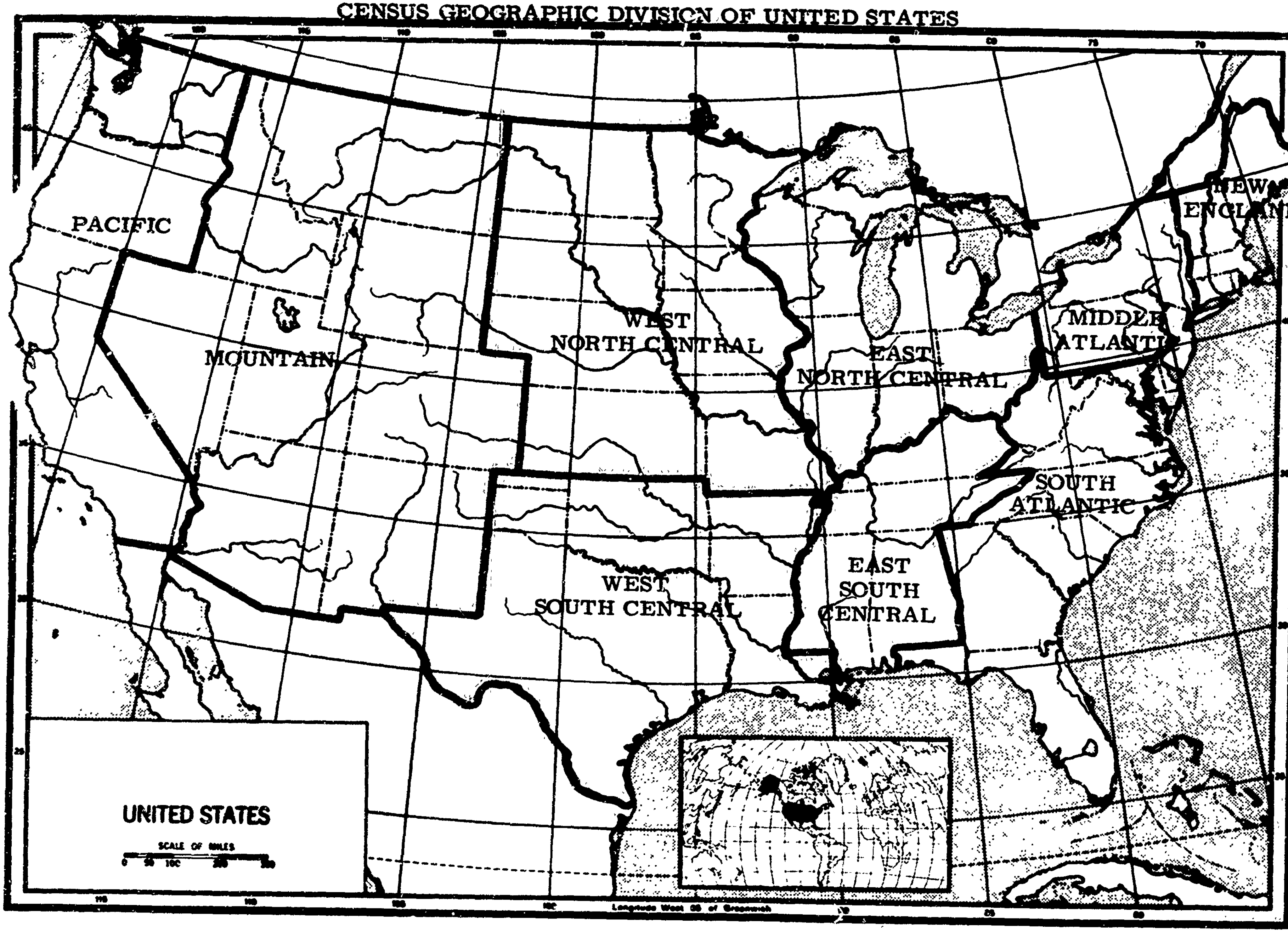
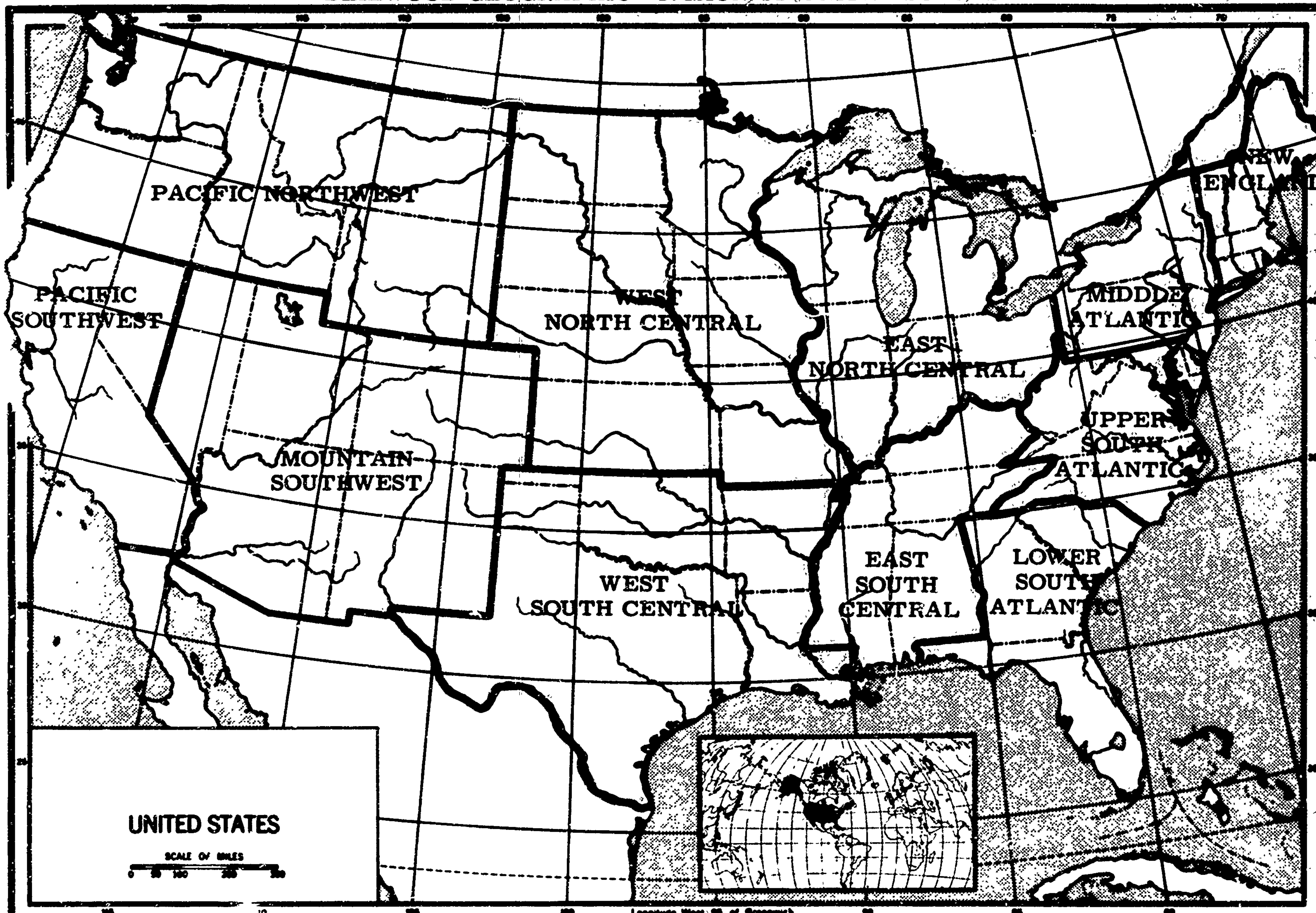


FIG. 2
DIKEWOOD GEOGRAPHIC DIVISION OF UNITED STATES



As noted above, any set of divisions will be somewhat arbitrary, but the set illustrated in Fig. 2 seems to possess more of the characteristics considered desirable than any other set readily discernible.

C. URBAN DEFINITIONS

As noted in the introduction, the choice of cities within a geographic-climatic region must be based on population and, to a lesser degree, on population density. There are four definitions for population groupings that should be considered. They are (1) the standard metropolitan statistical area, (2) the urbanized area, (3) the urban place, and (4) the nonoverlapping trade area. The definitions of these population groupings are given below.

A <u>standard metropolitan statistical area</u> (SMSA) is a county or group of contiguous counties that contains at least one city of 50,000 inhabitants or more, or "twin cities" with a combined population of at least 50,000. In addition to the county (or counties) containing such a city (or cities), contiguous counties are included in an SMSA if, according to certain criteria of the Bureau of the Census, they are essentially metropolitan in character and are socially and economically integrated with the central city.

An <u>urbanized area</u> contains at least one city of 50,000 inhabitants or more, or "twin cities" with a combined population of at least 50,000. In addition to its central city or cities, an urbanized area also contains

the incorporated and unincorporated closely-settled contiguous areas that together constitute its urban fringe. The urbanized area can be characterized as the physical city as distinguished from both the legal city and the metropolitan community. In general, urbanized areas represent the thickly settled core of the SMSA's.

An urban place is a concentration of population regardless of the existence of legally prescribed limits, powers, or functions. However, most urban places are incorporated as cities, towns, villages, or boroughs. Many of the political and geographical subdivisions of an urbanized area are themselves classified as urban places, as are the larger unincorporated places outside the urbanized areas.

The nonoverlapping trade area is the area contiguous to an urbanized area that depends on the urbanized area for its goods and services. In general, such areas are not precisely defined, and few statistics are available to describe them. However, the precise delineation of such areas would tell much about the size and character of the commercial and business areas of a city.

No one of the four definitions given above satisfies all of the requirements of this study. For example, the SMSA includes integral counties which may include much farm land. Hence, the population density for an SMSA may be lower than the density for the corresponding urbanized area or principal urbanized place within the area. Likewise, the population density for the

urbanized area may not represent the higher densities to be found in the core city. On the other hand, the population of the core city may represent only a small fraction of the total urban population. Examples of such extremes are illustrated by El Paso, Texas, and San Jose, California.

TABLE 1

EXAMPLES OF POPULATION EXTREMES IN URBAN AREAS

City	Population
El Paso	276,687
Urban fringe	441
San Jose	204,196
Urban fringe	398,609

The population of the urbanized area was chosen for all population comparisons in this study. This population should more nearly represent the true population influence on the character of the central business and commercial districts.

The population density of the core city of the urbanized area was also chosen for all density comparisons. This density should more nearly represent the true influence of the population density on the character of the residential areas of most concern in civil-defense planning.

D. URBAN-AREA STATISTICS

With the geographic-climatic regions as the basis for classification, all urbanized areas with more than 50,000 inhabitants were listed, and the following statistics were collected for each:

(1) Population of the urbanized area,

(2) Population density of the core city,

(3) Average high temperature for July, and

(4) Average low temperature for January.

The source of the population statistics was the United States Census of Population: 1960, Number of Inhabitants (Ref. 2). The source of the temperature statistics was a pair of maps published in 1960 by the United States Department of Commerce, Weather Bureau, Office of Climatology, which may be identified by the following Dewey Decimal number: 551.5250973.

E. URBAN-SIZE DEFINITIONS

To define large, medium, and small urbanized areas, the two or three largest areas, the median and one or two areas on either side of the median, and the two or three smallest urbanized areas from each geographic climatic region were tabulated. To be satisfactory it was felt that each geographic-climatic region should have at least one city in each size category. The following definitions were then made:

Large urbanized area--Greater than 500,000 inhabitants,

Medium urbanized area--Between 500,000 and 100,000 inhabitants, and

Small urbanized area--Between 100,000 and 50,000 inhabitants.

In addition, the following definition was made for completeness:

Very-small urbanized area--Between 50,000 and 2,500 inhabitants.

The data in Tables 2 and 3 were then assembled from these definitions.

F. SAMPLING PROBLEMS

As shown in Table 3, fourteen of the thirty-three size-location groups have three cities or less. In the small urbanized-area group in the Lower-South-Atlantic region, there is only one city (Albany, Georgia). These small groups make true statistical sampling difficult.

In selecting a large, medium, and small urbanized area from each region, it was hoped that high, medium, and low densities and a reasonable temperature spread could also be represented. Often this goal was not achieved due primarily to the small group size previously discussed and to the tendency of eastern cities to be densely populated while western cities (with a few exceptions) tend to be sparsely populated.

Finally, if two indistinguishable choices existed, the urbanized area with the higher target rating was selected for the survey. Again, the small size of some groups made it very difficult to include sufficient target cities. In an effort to include a few such urbanized areas, the selection principles discussed above were sometimes relaxed.

TABLE 2

PHYSICAL PARAMETERS OF CITIES BY SIZE CATEGORY

City Category	Population Limits Upper	Lower	Number of Cities	Total Population	Percent of Urban Population
Large	---	500,000	42*	67,151,211	53.6%
Medium	500,000	100,000	115**	24,104,377	19.2%
Small	100,000	50,000	60	4,592,899	3.7%
Very Small	50,000	2,500	~5000	29,420,263	23.5%
TOTAL				125,268,750	

* The New York area was considered to be four urbanized areas, and the Chicago area was considered to be two urbanized areas.

** Includes Honolulu, Hawaii.

TABLE 3

NUMBER OF CITIES BY SIZE-LOCATION CATEGORY

Geographic-Climatic Region	Number of Cities: Large	Medium	Small	Total
New England	2	13	7	22
Middle Atlantic	7	14	3	24
Upper South Atlantic	3	9	5	17
Lower South Atlantic	2	14	1	17
East North-Central	9	19	16	44
West North-Central	3	9	6	18
East South-Central	3	7	3	13
West South-Central	5	15	12	32
Mountain Southwest	2	6	2	10
Pacific Northwest	2	2	3	7
Pacific Southwest	4	6	2	12
TOTAL	42*	114**	60	216

* The New York area was considered to be four urbanized areas, and the Chicago area was considered to be two urbanized areas.

** Does not include Honolulu, Hawaii.

G. SELECTION OF CITIES

In nearly all regions the urbanized areas selected possess an element of arbitrariness, illustrated by the fact that three Dikewood personnel selected three separate sets. The intersection of any two of these sets was equivalent to approximately 50 percent of the total number of cities selected. The final list of urbanized areas for the survey represents a compromise selection from all three individual lists. Although the list selected for the survey can not be rigorously defended, it would be difficult to produce one significantly better.

After plotting the large, medium, and small urbanized areas from each geographic-climatic region on a map, it was evident that certain geographic areas were inadequately represented. To better represent these areas, ten very-small urbanized areas were also selected for the survey. All urbanized areas are shown on the map in Fig. 3. (The numbers correspond to the cities listed in Table 4.) The cities of Brooklyn, St. Louis, and Albuquerque were later added to this original list in order to salvage the data which had been obtained for them during a previous contractual effort (Contract No. OCD-OS-62-203).

H. ALLOCATION OF CITY BLOCKS

The survey effort must be allocated to the several urbanized areas; that is, the number of city blocks to be examined in each must be chosen.

FIG. 3
LOCATION OF SELECTED URBAN AREAS

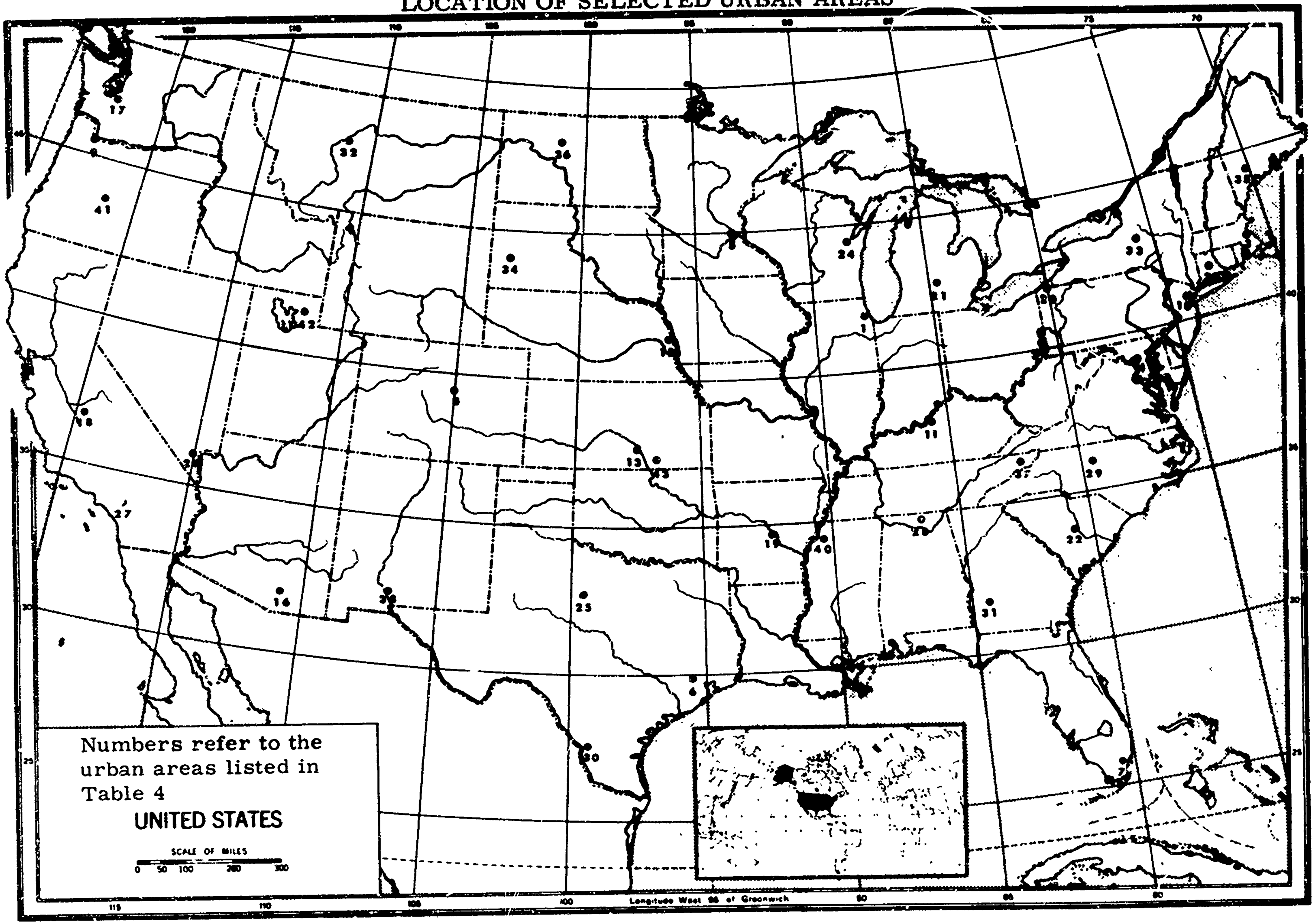


TABLE 4

BLOCK ALLOCATIONS AND PHYSICAL PARAMETERS OF SELECTED URBAN AREAS

	Selected Cities	Population	Density	Temperatures High	Temperatures Low	City Blocks Allocated
1.	Chicago, Ill.	6,220,913	15,836	84	20	500
2.	San Francisco, Calif.	2,430,663	15,553	72	44	300
3.	Boston, Mass.	2,413,236	14,586	80	22	300
4.	Washington, D. C.	1,808,423	12,442	87	28	260
5.	Minneapolis, Minn.	1,377,143	8,546	85	5	240
6.	Houston, Tex.	1,139,678	2,860	94	44	200
7.	Miami, Fla.	852,705	8,529	89	60	180
8.	Denver, Colo.	803,624	6,956	87	17	180
9.	Portland, Ore.	651,685	5,546	80	32	160
10.	Jersey City, N. J.	610,734	21,239	86	26	160
11.	Louisville, Ky.	606,659	6,841	90	28	160
12.	Omaha, Nebr.	389,881	5,891	90	13	120
13.	Wichita, Kan.	292,138	4,907	92	20	100
14.	Wilmington, Del.	283,667	6,065	88	26	100
15.	Mobile, Ala.	268,139	1,326	90	44	100
16.	Tucson, Ariz.	227,433	3,003	100	36	100
17.	Tacoma, Wash.	214,930	3,115	77	33	100
18.	Fresno, Calif.	213,444	4,683	100	36	100
19.	Little Rock, Ark.	185,017	3,810	94	32	80
20.	Erie, Pa.	177,433	7,364	80	22	80
21.	Lansing, Mich.	169,325	5,085	84	16	80
22.	Columbia, S. C.	162,601	5,295	92	38	80
23.	Waterbury, Conn.	141,626	3,882	84	18	80
24.	Green Bay, Wisc.	97,162	3,743	82	8	60
25.	Abilene, Tex.	91,566	1,446	96	31	60
26.	Las Vegas, Nev.	89,427	2,607	104	30	60
27.	Riverside, Calif.	84,332	2,077	80	20	60
28.	Huntsville, Ala.	74,970	1,427	92	34	50
29.	High Point, N. C.	66,543	2,048	88	32	50
30.	Laredo, Tex.	60,678	4,495	100	46	50
31.	Albany, Ga.	58,353	2,430	93	41	50
32.	Great Falls, Mont.	57,629	4,856	84	14	50
33.	Rome, N. Y.	51,646	670	82	12	50
34.	Rapid City, S. D.	42,399	2,701	88	9	40
35.	Lewiston, Me.	40,804	1,166	80	10	40
36.	Minot, N D.	30,604	4,310	84	-6	40
37.	Johnson City, Tenn.	29,892	2,742	84	28	40
38.	Las Cruces, N. M.	29,367	3,263	94	24	40
39.	Weirton, W. Va.	28,201	1,516	87	23	40
40.	Clarksdale, Miss.	21,105	6,030	94	35	40
41.	Bend, Ore.	11,936	2,210	84	18	40
42.	Brigham City, Utah	11,728	1,020	90	14	40
43.	Winfield, Kan.	11,117	3,833	95	24	40
	TOTAL	22,630,556				4700

Again, some arbitrariness is involved, but to place the allocation on some rational basis, the number of blocks assigned to each large, medium, and small urbanized area was computed as follows:

$$B \approx 0.2\sqrt{P}$$

where,

B = Number of blocks to be examined, and

P = Urban population.

Forty blocks were allocated to each "very-small" urbanized area. The results of this block allocation are also given in Table 4.

After observing some of the early data, it was felt that better results could be obtained by increasing the number of cities beyond the twenty originally estimated for a better geographical coverage. At the same time, it was felt that the number of blocks to be analyzed could be cut below the original estimate of 6000. Therefore, this cut was made early so that the sampling technique would not be disturbed at a later date.

CHAPTER III

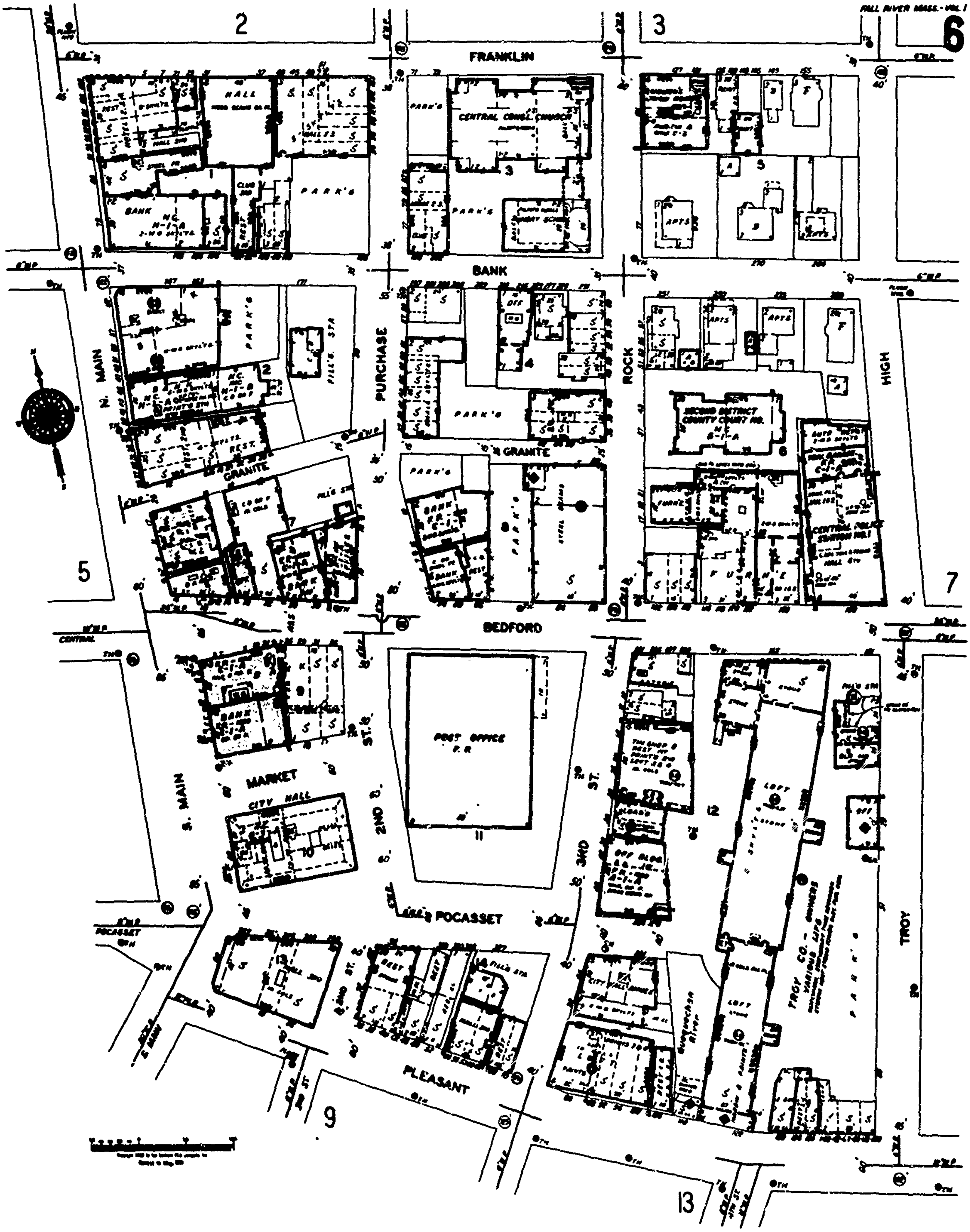
SELECTION OF URBAN BLOCKS

A. INTRODUCTION

The Sanborn maps were chosen as the principal source of data for the building use and construction survey. These maps, which are drawn to scale (50 to 400 feet per inch), show size and many construction and use details for all buildings in selected urban areas. A sample is shown in Fig. 4. Even a cursory examination of these maps for a particular city reveals the diversity of size, spacing, arrangement, construction, and use of the various units. At first it might seem that no pattern could possibly exist, but from an examination of a few cities, the restrictions necessary for patterns to emerge become evident.

One of the first things that is noted from a detailed examination of the Sanborn maps for several cities is that cities are made up of both homogeneous and heterogeneous areas, that is, mixed in the sense of building use and construction. For example, large lightly-constructed single-roomed buildings are characteristic of warehouse areas, whereas small many-roomed buildings are characteristic of residential areas. These structures are quite different, yet there are urban areas where they exist side by side. Hence, the principal restriction necessary for urban building use and construction patterns to emerge is the homogeneity of areas that are to be examined and described.

SAMPLE SANBORN MAP



The study of urban areas in general and a description of some specific types of homogeneous areas in terms of two criteria, building construction and use, are the first tasks of this study. Chapter II of this report described the selection of a sample of urban areas. This chapter describes the selection of blocks within an urban area.

B. LAND-USE SURVEY

After the urban areas were selected as previously described, specific blocks within each area were selected for the survey. The regions within an urban area that are homogeneous with respect to building use and construction may be classified broadly into three general categories: retail-office, manufacturing-commercial, and residential. In some cities, particularly the larger ones, residential areas may be further divided into single-unit and multiple-unit dwellings. These four gene al land-use classifications formed the basis for selecting specific urban blocks for this study.

For some cities, it is possible to subdivide these four classifications into more precise categories. The subdivisions chosen for this study are naturally arbitrary, but they do represent considerable experience and knowledge of urban areas. The four major classifications and the subdivisions that were considered desirable for this study are given in Table 5.

TABLE 5

TYPICAL LAND USES

1. Retail and Office

    a. "Downtown" or center of the major business area*

    b. Satellite or suburban shopping and office area

2. Commercial

    a. Light manufacturing

    b. Heavy manufacturing

    c. Warehouses

3. Residential--Multiple-Unit Dwellings

    a. More than two-story (high) apartment buildings

    b. One- and two-story (low) multiplexes

4. Residential--Single-Unit Dwellings

    a. Large residences, greater than 2000 sq ft

    b. Small residences, less than 2000 sq ft

    c. Run-down (blighted) residential area

---

* Code is given as 1a.

All of these categories are self-explanatory with the possible exception of category 4c, the blighted residential area. This category was originally meant to be included in the single-unit residential dwellings; however, many of the replies obtained from the land-use survey categorized slum areas such as Harlem as blighted residential areas. Since such areas contain many high-rise apartment buildings, construction such as brick and American reinforced concrete were overemphasized. Due to this dual meaning applied to blighted residential areas, this category eventually had to be deleted from the list of land uses as described in the concluding remarks of Chapter VI.

The selection of the urban areas and the allocation of effort to these areas according to their population, as shown in Table 4, was discussed in Chapter II. This allocation of effort, which was stated in terms of the specific number of blocks to be surveyed in each urban area, was further subdivided among the land-use classifications and subdivisions of Table 5. The principal problem in this phase of the study was the selection, according to this final allocation, of specific blocks for examination in each of the urban areas. Without detailed information on land use in each urban area, specific blocks could not be selected; hence, specific volumes of Sanborn maps could not be selected and ordered for the building use and construction survey. To provide land-use data, a preliminary land-use survey was required.

In planning the land-use survey, the first two problems concerned (1) the specific cities that were to be surveyed and (2) the method of performing the survey. For most cities below 100,000 population, Sanborn provides only one volume of maps. Thus, for twenty of the urban areas there was no question concerning which Sanborn volumes to order. In addition, project personnel possessed sufficient knowledge of land use in three other urban areas--Minneapolis, Denver, and Wichita--for the building use and construction survey. Hence, land-use information was needed for only about one-half of the urban areas.

A direct-mail survey was chosen since it was much less expensive than personal trips to each of the cities. The first problem presented by a mail survey was who to contact in each city. The person or organization contacted had to have some knowledge of land use. Urban-planning offices have detailed knowledge of land use, but not all cities have planning offices. City governments might be able to supply land-use information, but they may also be unaccustomed to answering such questions, thus decreasing the probability of an acceptable response. Another public (but not necessarily governmental) organization was needed. Since most urban areas have a Chamber of Commerce, this organization was chosen as the source of land-use information. Chambers of Commerce know their respective urban areas well and are accustomed to answering similar questions. In addition to these attributes, the Albuquerque Chamber of Commerce was

able to supply the name and address of the executive secretary of any Chamber of Commerce in the United States. As with any direct-mail survey, personal correspondence with a specific individual rather than with an office enhances the probability of a satisfactory reply.

For this study a detailed description of land use was not required; a simple indication of where typical areas existed according to the definitions of Table 5 was considered to be sufficient. The survey letter asked for typical areas to be marked on a city map and sent to Dikewood. A copy of Table 5 and a sample map of Albuquerque appropriately marked were enclosed with each survey letter.

The useable survey response of approximately 70 percent was about average for this type of direct-mail approach. The results of this land-use survey were most useful in locating homogeneous areas for the building use and construction survey.

C. SELECTION OF BLOCKS

It was soon discovered through experien[illegible]le Sanborn volume would yield on the average no more than 60 blocks in homogeneous land-use groups. It was also found that a trained map reader could read, measure, and record the data for approximately 40 urban blocks per week. The results of the land-use survey, together with the above data, permitted efficient and systematic ordering of Sanborn volumes to yield the specific land-use areas needed for the building use and construction survey.

As each volume of Sanborn maps arrived, the homogeneous areas were located and correlated with the results of the land-use survey. Specific homogeneous areas of six or more contiguous blocks were then selected for the survey. When blocks were poorly defined as in industrial regions, areas equivalent to six or more well-defined blocks nearby were selected. When homogeneous areas could not be found, mixed areas with a high percentage of one basic land use were selected.

The number and size of contiguous areas chosen from each volume depended on the area types available in the volume and the area types required to complete the survey of the particular city. A few volumes from the larger cities contained little more than one large homogeneous area. Thus, in a few cases a very large contiguous area representing a single land-use category was chosen for the survey. For small and very-small urban areas, homogeneous areas as large as six blocks were sometimes difficult to find. Although some cities did not contain all types of land-use areas, as many types as existed were included in the building use and construction survey for each city studied.

D. SANBORN MAPS

The Sanborn Map Company has been surveying the distribution and characteristics (use and construction) of urban buildings and mapping this information for fire-insurance companies for almost 100 years. The basic purpose for preparing these maps was to provide fire-insurance underwriters

with the building use and structural data necessary for evaluating fire risks and insurance rates. The Sanborn maps seldom, if ever, cover all of an urban area. Instead, they cover primarily the congested areas where ground cover is high and the fire risks at one site may affect the risks at adjacent sites.

All of the information recorded on these maps concern fire risks and in some way affect fire-insurance rates. Hence, it is incidental (but fortunate) that these maps contain information useful for this study. In some cases, information considered necessary for the building use and construction survey may not be recorded on the maps. Similarly, much information considered unnecessary for the survey may also appear on the maps.

When the Sanborn maps are evaluated as the data source for the survey, one apparent defect is the limited area covered by the maps. Since the maps are basically used for estimating fire risks, those areas sufficiently congested to be fire hazards are the primary ones to be mapped. Recent suburban developments and even older residential areas where the built-up fraction is low are seldom mapped. All retail, commercial, and manufacturing areas, as well as most high-rise apartment areas, are mapped. Most of the areas that are not mapped by Sanborn are the newer residential areas. Table 6 illustrates this defect by presenting both the approximate areas mapped by Sanborn and the urban area given by the Bureau of the Census (1960) for several cities chosen at random from Table 4.

TABLE 6

COMPARISON OF URBAN AREAS

City	Urban Area (sq mi) Central City	Total	Area Covered by Sanborn Maps (sq mi)
Minneapolis-St. Paul, Minn.	108.7	657.3	116.8
Denver, Colo.	71.0	166.6	46.6
Wichita, Kan.	51.9	79.7	24.3
Erie, Pa.	18.8	56.7	13.9

CHAPTER IV

DATA RECORDED

A. ESSENTIAL INFORMATION

The information considered essential for each block surveyed may be grouped into three categories:

(1) Location data
  (a) City
  (b) Street boundaries

(2) Classification data (land use)

(3) Dimensional data
  (a) Map scale
  (b) Street lengths
  (c) Street widths
  (d) Block areas

In addition, the following block information was necessary for quality control of the reading process:

(1) Sanborn volume number

(2) Sanborn page number

(3) Sanborn block number

(4) Data sheet number

(5) Building street address

(6) Reader's initials

All of the above block information were copied directly or obtained by simple measurements from the Sanborn maps.

To describe a building the following information was also recorded:

(1) Number of floors

(2) Building height

(3) Building ground area

(4) Building use

(5) Building construction

With the exception of some residential structures (houses, garages, sheds, etc.), the number of floors for a building was usually recorded on the Sanborn maps. When the number of floors was not recorded, it was often obvious that the structure had only a single floor. The height of a building was recorded for approximately 10 percent of the total structures, but for approximately 33 percent of the non-residential structures.

In addition to the block and building information required for the building use and construction survey, the following census location and population data were recorded for each block:

(1) Data sheet number

(2) Standard location number

(3) Census tract number

(4) Census block number

(5) Block residential population

(6) Standard location population
  (a) Residential
  (b) Day
  (c) Night

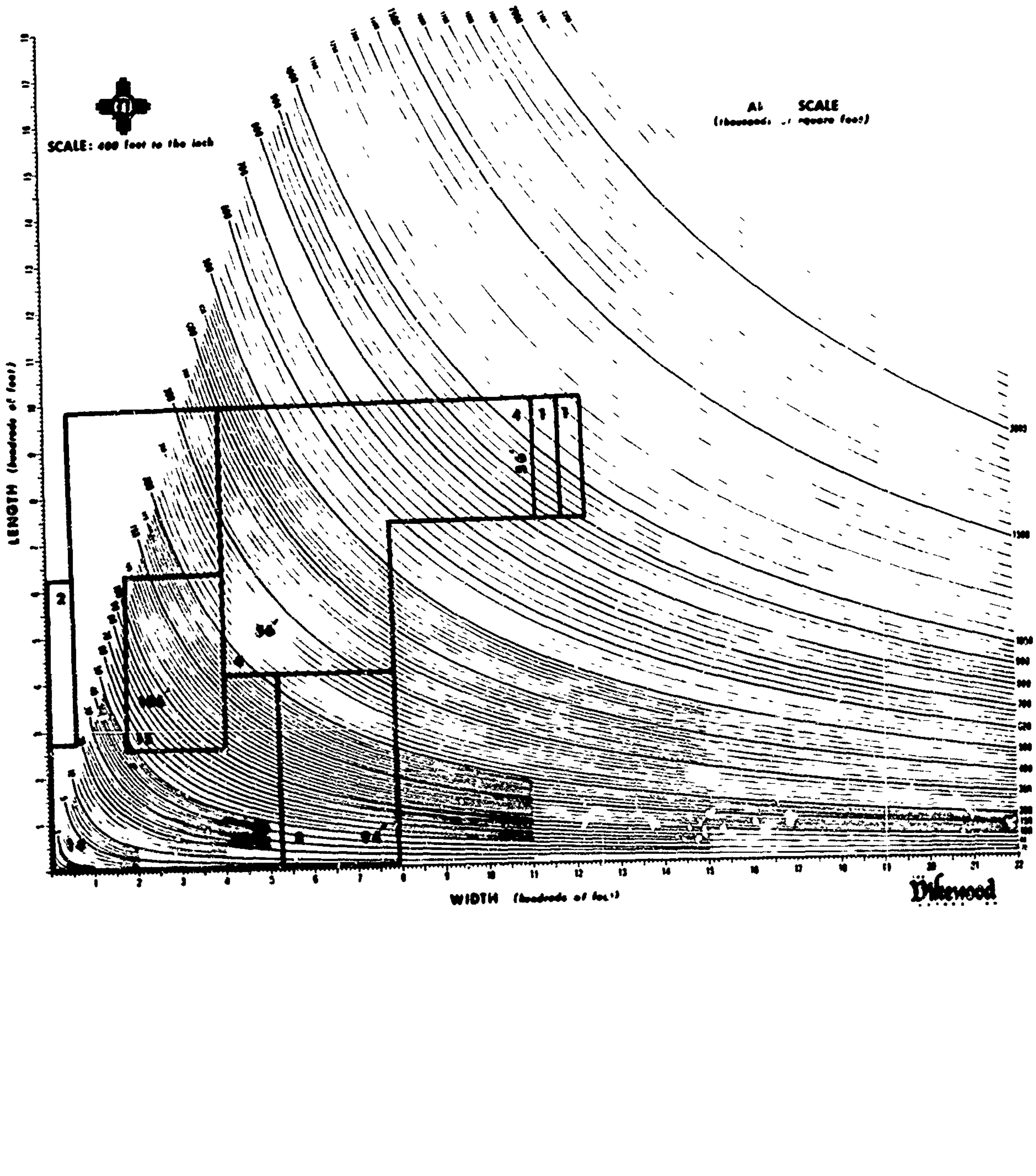
B. AREA-SCALE READER

Building areas were obtained by measurements from the Sanborn maps (drawn to scale). For these measurements Dikewood designed an area-scale reader. This reader consisted of many simple hyperbolas plotted with the positive x- and y-axes as asymptotes on transparent plastic sheets. The hyperbolas, or isograms, represented equal rectangular areas. Figure 5 illustrates the reader concept and its use. As shown in Fig. 5, the intersection of the axes (origin) was positioned over the corner of a rectangular building with the axes lying along two of the building's sides. The area of the building was then determined by identifying the area isogram that passed over the corner opposite the origin. Since most structures have an irregular shape, the area recorded for a building was usually the sum or difference of two or more individual readings. Such a sum or difference would be required for the building shape illustrated in Fig. 5.

A program was prepared for Dikewood's IBM-7044 computer to calculate the points on 216 area isograms, of which 139 were plotted on a 100 foot-per-inch scale to produce a master reader. This master was then photographically reduced to both 200 and 400 foot-per-inch scales. In general, all building ground areas were read with the 400 foot-per-inch reader, and all land or block areas were read with the 200 foot-per-inch reader. True areas were later computed by multiplying these measured or recorded areas by the square of the ratio of the map scale to the reader scale.

FIG. 5

DIKEWOOD AREA SCALE



C. BUILDING USE

The building use, recorded on the Sanborn maps for at least 99 percent of the buildings, was coded and recorded on the data sheets. To minimize translation problems, the Sanborn use codes were utilized when possible. These codes are summarized in Table 7. When the building use was not recorded, the map readers assumed one based on size, location, land use, and/or surrounding structures. If this procedure failed, the building in question was coded commercial.

D. BUILDING CONSTRUCTION

Since structure is the primary basis for fire-insurance rates, some construction information was always recorded for each building mapped. Sometimes the information recorded was difficult or impossible to interpret as, for example, the building that had load-bearing, brick-curtain walls. Sometimes construction was assumed; for example, dwellings were always wood frame unless otherwise noted on the maps. For each building included in the use and construction survey, one to three construction codes were used to summarize the construction data recorded on the Sanborn maps. These codes are summarized in Table 8.

Some of the construction codes were designated primary construction codes. Others were designated secondary codes while the remainder were designated tertiary codes. If more than one code were required to describe

TABLE 7

BUILDING USE CODES

A	Auto garage (private)
AD	Auto, first floor; dwelling, second floor
APT	Apartment
APTS	Apartment
AUD	Auditorium, movie, library, lodge, bowling alley, or hall
B	Bank
C	Church
CL	Club (YMCA, Salvation Army, etc.)
COM	Commercial, small repair, or service business (including Chamber of Commerce, clinic, tire repair, plumbing, undertaker, auto sales, parking, laundry, laboratory, ice house, packing plant, loft, etc.)
D	Dwelling
F	Flat
G	Garage
GO	Gas and oil
GOV	Government
H	Hotel
HOSP	Hospital
M	Motel
MFG	Manufacturing
O	Office
P	Park
R	Rooming and boarding house, boys home, girls home, nursing home, etc.
REST	Restaurant
S	Store

TABLE 7 (Continued)

BUILDING USE CODES

SD	Store, department
SCH	School
SHED	Shed
SHEDS	Shed
SS	Service station
T	Tenement
TELE	Telephone exchange
U	Utility
V	Vacant
VO	Vacant and open
WHO	Warehouse, produce house, grain elevator, etc.

TABLE 8

DIKEWOOD BUILDING CONSTRUCTION CODES*

A	Adobe*
B	Brick or stone
CB	Cement brick
T	Tile (hollow ceramic block)
BF	Brick- or tile-faced front
BV	Brick or stone veneered
WF	Wood frame
I	Iron (wood frame with iron cladding)
P	Plastic
CF	Concrete frame
CFR	Concrete floors and roof
CFFR	Concrete frame, floors, and roof
SF	Steel frame
SFC	Steel frame; concrete floors and roof
AC	Aluminum curtain walls
BC	Brick or tile curtain walls
CC	Concrete curtain walls
GC	Glass curtain walls
WC	Wood curtain walls
LB	Load bearing
PW	Pilastered walls
WT	Wood roof trusses
BP	Brick posts
CP	Concrete posts
IP	Iron posts
SP	Steel posts
WP	Wood posts
UG	Under ground
NONE	Parks, etc.

* These codes are always used alone and not in combination with other codes. (The data came from color-coding on the Sanborn maps.)

TABLE 8 (Continued)

SANBORN CONSTRUCTION CODES FOR FIRE-RESISTIVE STRUCTURES*

Framing		Floors		Roof	
Code	Structural Unit	Code	Structural Unit	Code	Structural Unit
A.	Reinforced concrete frame	1.	Reinforced concrete; reinforced concrete with masonry units; pre-cast concrete; gypsum slabs or planks	a.	Reinforced concrete; reinforced concrete with masonry units; reinforced gypsum concrete; pre-cast concrete; gypsum slabs or planks
B.	Reinforced concrete joists, columns, beams, trusses, arches, masonry piers	2.	Concrete on metal lath; incombustible form boards; paper-backed wire fabric; steel deck; cellular, ribbed, or corrugated steel units	b.	Concrete or gypsum on metal lath; incombustible form boards; paper-backed wire-fabric; steel deck; cellular, ribbed, or corrugated steel units
C.	Protected steel frame	3.	Open steel deck or grating	c.	Incombustible composition boards with or without insulation; masonry or metal tiles
D.	Individually protected steel joists, columns, beams, trusses, arches			d.	Steel deck; corrugated metal or asbestos-protected metal with or without insulation
E.	Indirectly protected steel frame				
F.	Indirectly protected steel joists, columns, beams, trusses, arches				
G.	Unprotected steel frame				
H.	Unprotected steel joists, columns, beams, trusses, arches				
O.	Masonry bearing walls				

* Example: Reinforced concrete frame, floors, and roof would be indicated by a code of A1a. (These codes are always given in groups of three indicating the framing, floor, and roof construction.)

the construction of a building, then the primary, secondary, and tertiary designations were used to determine the order for the codes on the data sheets. This classification was an important basis for the computer sorting of the codes to determine the predominant structural type as described below. Since three codes might not be sufficient to describe completely the construction of a building, a blank for additional construction details or comments was also provided on each data sheet.

Samples of the data sheets used for recording all of the data are illustrated in Figs. 6 and 7. The four blanks for the census data in the heading of Fig. 6 were not used. They were replaced by the census data sheet of Fig. 7.

The classification, categorization, and correlation of the construction codes in Table 8 are given in Tables 9, 10, and 11, respectively. These latter three tables show how the construction codes from the original building data were sorted in condensing the information for a block summary, allowing only the six primary construction types for which casualty curves exist (from Contract No. OCD-OS-62-203).

E. QUALITY CONTROL

A simple, but effective, quality-control system to assure reasonable reader accuracy was designed. The work standard was established at 40 blocks per week per reader. The supervisor reread one block per reader per week or 2.5 percent of the total blocks surveyed. To assure

FIG. 6

CONSTRUCTION DATA SHEET

LOCATION	BOUNDARY	Street Names	Width	Length	SHEET NO.
City ____ ( )	Upper				Reader Initials
Sanborn Vol.	Left				Census Track
Page & Block	Lower				Census Block
Area Type	Right				Block Pop (day)
Area Scale	Block Area				Block Pop (nite)

Street and Number	Floors	Height	Area	Use Code	Construction Codes 1	2	3	Construction Details

FIG. 7

CENSUS DATA SHEET

Sheet No.	Standard Location No.	Census Tract	Census Block	Block Pop.	Standard Location Pop.		
				Res.	Res.	Day	Night

TABLE 9

CLASSIFICATION OF CONSTRUCTION CODES

Primary Codes	Secondary Codes*
A	BF
B	P
BV	AC
CB	GC
CF	WC
CFR	PW
CFFR	WT
I	BP
LB	CP
SF	IP
SFC	SP
T	WP
WF	NONE
Let., No., let.	
BC‡	
CC‡	
UG‡	

---

* Ignore secondary construction codes in analysis.

‡ These secondary construction codes are used in a few instances.

TABLE 10

CATEGORIZATION OF PRIMARY CONSTRUCTION CODES*

1. Wood Frame (WF)

I
WF

2. Brick (BR)

A	CB	O1a	O2a	O3a
B	LB	O1b	O2b	O3b
BV	T	O1c	O2c	O3c
		O1d	O2d	O3d

3. American Reinforced Concrete (ARC) (LSF and HSF→ARC if > 2 stories)

CF	A1a	B1a	A2a	B2a	A3a	B3a
CFR	A1b	B1b	A2b	B2b	A3b	B3b
CFFR	A1c	B1c	A2c	B2c	A3c	B3c
	A1d	B1d	A2d	B2d	A3d	B3d

4. Japanese Reinforced Concrete (JRC)

A1a, CC
CFFR, CC
If the "building-use" code was A, the category was changed to ARC.

5. Heavy Steel Frame (HSF) (≤ 2 stories; LSF→HSF if > 30 ft)

SFC	C1a	E1a	G1a	C2a	C2b	C3a
	C1b	E1b	G1b	D2a	D2b	D3a
	C1c	E1c	G1c	E2a	E2b	E3a
	C1d	E1d	G1d	F2a	F2b	F3a
	D1a	F1a	H1a	G2a	G2b	G3a
	D1b	F1b	H1b	H2a	H2b	H3a
	D1c	F1c	H1c			
	D1d	F1d	H1d			

If code CC was also given, the category was changed to ARC.

6. Light Steel Frame (LSF) (≤ 2 stories; ≤ 30 ft)

SF	C2c	C2d	C3b	C3c	C3d
	D2c	D2d	D3b	D3c	D3d
	E2c	E2d	E3b	E3c	E3d
	F2c	F2d	F3b	F3c	F3d
	G2c	G2d	G3b	G3c	G3d
	H2c	H2d	H3b	H3c	H3d

If code BC was given, the category was changed to HSF.
If code CC was given, the category was changed to ARC.

---

* The code UG was classified as miscellaneous.

TABLE 11

CORRELATION OF PRIMARY CONSTRUCTION CODES

WF	= 1
BR	= 2
ARC	= 3
JRC	= 4
HSF	= 5
LSF	= 6

A, B	= 2	BV, SF	= 5*	CFFR, I	= 3
A, BV	= 2	BV, SFC	= 3	CFFR, T	= 3
A, CB	= 2	BV, T	= 2	I, SF	= 6*
A, I	= 2	BV, WF	= 2	I, T	= 2
A, T	= 2	CB, CF	= 3	I, WF	= 1
A, WF	= 2	CB, CFR	= 3	LB, A	= 2
B, BV	= 2	CB, CFFR	= 3	LB, B	= 2
B, CB	= 2	CB, I	= 2	LB, BV	= 2
B, CF	= 3	CB, SF	= 5*	LB, CB	= 2
B, CFR	= 3	CB, SFC	= 3	LB, CF	= 3
B, CFFR	= 3	CB, T	= 2	LB, CFR	= 3
B, I	= 2	CB, WF	= 2	LB, CFFR, CC	= 4
B, SF	= 5*	CF, CFR	= 3	LB, I	= 1
B, SFC	= 3	CF, CFFR, CC	= 4	LB, SF	= 6*
B, T	= 2	CF, I	= 3	LB, SFC	= 5*
B, WF	= 2	CF, T	= 3	LB, T	= 2
BV, CB	= 2	CFR, CFFR, CC	= 4	LB, WF	= 1
BV, CF	= 3	CFR, I	= 3	SF, SFC	= 5*
BV, CFR	= 3	CFR, SF	= 5*	SF, T	= 5*
BV, CFFR	= 3	CFR, SFC	= 3	SFC, T	= 3
BV, I	= 2	CFR, T	= 3	T, WF	= 2

5, CC=3	2, 1=2	3, 4=3
6, BC=5*	2, 3=3	3, 5=3
6, CC=3	2, 4=3	3, 6=3
UG =MISC	2, 5=5*	4, 1=3
	2, 6=5*	4, 5=3
	3, 1=3	4, 6=3
		5, 6=5*

*For buildings ≤ 2 stories; for buildings > 2 stories, change from 5 (HSF) or 6 (LSF) to 3 (ARC).

that the data sheets were properly completed, the supervisor also made a cursory examination of all completed data sheets. In addition, the key-punch verifiers also scanned the original data sheets for correctness of codes and completeness of data.

F. PREPARATION FOR ANALYSIS

The data sheets were used as source documents for punching and verifying standard IBM cards. Tables 12 and 13 list the items punched from the data sheets and the card columns into which each item was punched for both block and building data, respectively. A computer program was prepared to edit the data punched in the cards and to record the edited data on magnetic tape for later analysis.

The basic unit of information (binary record on tape) consists of the data concerned with all of the buildings in a block together with the necessary facts to describe the block. The block description is contained on a punched card referred to as the block data card (Table 12), and individual building information is contained on the building data card (Table 13).

The computer program checked the quantities entered in the column fields shown in Tables 12 and 13 to assure the correctness of these quantities. If a field was found to contain an incorrect quantity as determined from a predetermined list of correct quantities (Tables 7 and 8), the erroneous card was deleted from the data to be put on tape for that block.

TABLE 12

BLOCK DATA CARD

	Item	Characters Required	Starting Column No.
1.	Card type 1	1	1
2.	Sequential sheet number	5	3
3.	City code	2	10
4.	Sanborn volume	3	13
5.	Sanborn page	5	17
6.	Sanborn block	4	22
7.	Area type (land-use) code	2	27
8.	Sanborn area scale	3	30
9.	Upper street:		
	Width	3	35
	Length	4	39
10.	Left street:		
	Width	3	45
	Length	4	49
11.	Lower street:		
	Width	3	55
	Length	4	59
12.	Right street:		
	Width	3	65
	Length	4	69
13.	Block area	5	75

TABLE 13

BUILDING DATA CARD

	Item	Characters Required	Starting Column No.
1.	Card type 2	1	1
2.	Sequential sheet number	5	3
3.	Number of floors	3	10
4.	Building height	3	15
5.	Building ground area	5*	20
6.	Building use code	5	30
7.	Building construction codes:		
	No. 1	4	40
	No. 2	4	50
	No. 3	4	60

*The last digit was used to indicate the reader area scale actually used. No asterisk indicates 400 ft/inch; an asterisk indicates 200 ft/inch.

The only exception to this rule occurred when an error was found in a block data card (Table 12); in that case the whole block was omitted from the tape.

Each time new data cards were added to the tape, the blocks on the tape were automatically checked for correct ordering; if any were found to be out of sequence, a message to that effect was produced. After several blocks were put on the tape, the tape was rewritten by a correcting program which corrected the blocks with the missing data and inserted skipped blocks as necessary.

A third type of card known as the census data card was utilized to tie the census data and standard location numbers together with the block and building data cards. Table 14 shows the items which were punched from the data sheets and the card columns into which each item was punched.

G. SUMMARIZING THE DATA

In addition to the computer programs to put the IBM card data onto magnetic tape, make corrections, and allow insertions, the block summary program tabulated these voluminous data by construction type and land use. This program was developed so that all of the information would be on an additional tape summarized by blocks instead of by buildings. All summary work was done with the block tape since it could be run in approximately three minutes, whereas the complete building tape took about twenty minutes. Summaries were developed for the following areas so that statistical analyses could be made:

TABLE 14

CENSUS DATA CARD

	Item	Characters Required	Starting Column No.
1.	Card type 3	1	1
2.	Sequential sheet number	5	5
3.	Standard location number	8	13
4.	Census tract	7	24
5.	Census block	5	34
6.	Block population:		
	Residential	5	42
7.	Standard location population:		
	Residential	6	50
	Day	6	59
	Night	6	68

(1) Urban blocks

(2) Standard locations

(3) Urban Sanborn-volume areas

(4) Urban areas (cities)

(5) Urban areas by size (L, M, S, and VS)

(6) Urban size--Region combinations

(7) Regions of U. S.

(8) Entire U. S.

Appendix A presents the format of the data recorded on the large building data tape, and Appendix B describes the format of the data recorded on the small block summary tape. These tapes were used to process the voluminous data recorded during this project.

Table 15 summarizes the number of city blocks allocated and read from the Sanborn maps. It should be noted that data were recorded from 5284 blocks, requiring some 200,000 IBM cards. The cities of Brooklyn, St. Louis, and Albuquerque were added to the original list in order to salvage the data which had been obtained for them during a previous contractual effort (Contract No. OCD-OS-62-203). The city codes utilized in the computations are given by each city in Table 15.

TABLE 15

BLOCK ALLOCATIONS OF SELECTED URBAN AREAS

Selected Urban Areas	Blocks Allocated	Blocks Read
1. Chicago, Ill. (38)*	500	390
Cook County, Ill. (43)		46
Oak Park, Ill. (39)		69
2. San Francisco, Cal. (37)	300	307
3. Boston, Mass. (11)	300	159
Cambridge, Mass. (12)		81
Newton, Mass. (14)		39
Waltham, Mass. (13)		60
4. Washington, D. C. (9)	260	214
Arlington, Va. (16)		34
Bethesda, Md. (17)		12
Chevy Chase Village, Md. (18)		10
5. Minneapolis, Minn. (15)	240	233
6. Houston, Texas (24)	200	177
7. Miami, Fla. (40)	180	112
Coral Gables, Fla. (41)		55
8. Denver, Colo. (10)	180	220
9. Portland, Ore. (55)	160	228
10. Jersey City, N.J. (44)	160	115
11. Louisville, Ky. (48)	160	120
12. Omaha, Nebr. (23)	120	137
13. Wichita, Kan. (8)	100	150
14. Wilmington, Del. (49)	100	107
15. Mobile, Ala. (25)	100	104
16. Tucson, Ariz. (47)	100	113
17. Tacoma, Wash. (36)	100	103
18. Fresno, Calif. (42)	100	104
19. Little Rock, Ark. (46)	80	104
20. Erie, Pa. (45)	80	96
21. Lansing, Mich. (52)	80	81
22. Columbia, S.C. (51)	80	112
23. Waterbury, Conn. (26)	80	72
24. Green Bay, Wis. (28)	60	59
25. Abilene, Tex. (32)	60	74
26. Las Vegas, Nev. (31)	60	73
27. Riverside, Calif. (30)	60	57
28. Huntsville, Ala. (29)	50	63
29. High Point, N.C. (33)	50	47

* Numbers in parenthesis are city codes.

TABLE 15 (Continued)

BLOCK ALLOCATIONS OF SELECTED URBAN AREAS

Selected Urban Areas	Blocks Allocated	Blocks Read
30. Laredo, Tex. (34)*	50	71
31. Albany, Ga. (35)	50	46
32. Great Falls, Mont. (50)	50	53
33. Rome, N.Y. (27)	50	43
34. Rapid City, S. D. (54)	40	51
35. Lewiston, Me. (53)	40	41
36. Minot, N.D. (2)	40	55
37. Johnson City, Tenn. (7)	40	31
38. Las Cruces, N.M. (21)	40	71
39. Weirton, W.Va. (4)	40	33
40. Clarksdale, Miss. (6)	40	76
41. Bend, Ore. (5)	40	52
42. Brigham City, Utah (3)	40	26
43. Winfield, Kan. (1)	40	48
44. Brooklyn, N.Y. (19)	0	30
45. St. Louis, Mo. (22)	0	107
46. Albuquerque, N.M. (20)	0	113
Total	4700	5284

* Numbers in parenthesis are city codes.

CHAPTER V

COMPUTER SUMMARIES FOR LARGE AREAS

This chapter presents some typical computer summaries for large, medium, and small urban areas in Tables 16 through 18; the eleven geographic regions in Tables 19 through 29; and the entire United States in Table 30. Two individual tables are presented for each item.

The first of two tables for each summary gives the percent construction of each type, according to the above-ground floor area, for each land use in the area. The second table presents the total ground area surveyed and the total ground floor area (both in square feet) for each land use. (The letter E followed by a number represents 10 to the power given by the number.) The percentage built-up and the actual and normalized block counts are also given for each land use. (The normalized blocks are used when it is required that all of the blocks be of uniform size.)

It should be mentioned that the blighted residential areas appear to have a significant percentage of American reinforced-concrete (ARC) structures (high-rise apartment buildings) in the larger urban areas. Since most of the blighted areas were found in the larger cities, the United States summary, for example, tends to show a higher-than-normal percentage of ARC structures as compared to those found in the medium and small cities. Due to this result and the fact that the high-rise apartment buildings were already represented in another land-use, the blighted residential category was eventually deleted from the list of land uses or typical areas.

TABLE 16

LARGE CITIES, OVER 500K

PERCENT ABOVE-GROUND FLOOR AREA

Code	Land Uses	WF	BR	ARC	JRC	HSF	LSF	Total
		Construction Types						
1A	Downtown Business Area	2.32	33.75	63.27	0.37	1.14	0.15	48.48
1B	Suburban Business Area	10.26	52.14	33.57	0.32	3.25	0.47	3.66
2A	Light Manufacturing	11.61	35.71	45.22	1.64	3.60	2.21	7.06
2B	Heavy Manufacturing	21.46	25.73	42.08	1.57	7.31	1.84	11.71
2C	Warehouses	10.19	43.32	36.38	1.28	5.90	2.93	4.25
3A	High Apartment Bldgs	6.66	35.06	57.86	0.	0.41	0.01	4.85
3B	Low Apartment Bldgs	36.07	47.40	13.99	0.	0.70	1.84	0.32
4A	Large Residences	33.42	53.93	10.96	0.02	1.38	0.29	8.65
4B	Small Residences	53.79	43.94	1.61	0.14	0.40	0.12	6.49
4C	Blighted Residences	29.03	48.15	22.31	0.	0.51	0.00	4.53
	Total	13.40	36.71	46.48	0.56	2.22	0.63	100.00

PERCENT GROUND AREA BUILT-UP

Code	Land Uses	Total Ground Area Surveyed (ft^2)	Total Ground Floor Area (ft^2)	Percent Built-Up	Block Counts Actual	Block Counts Norm.
1A	Downtown Business Area	0.13428739E 09	0.55573759E 08	41.38	826	579.0
1B	Suburban Business Area	0.32009466E 08	0.91698741E 07	28.65	145	138.0
2A	Light Manufacturing	0.52045436E 08	0.14593090E 08	28.04	117	224.4
2B	Heavy Manufacturing	0.71257162E 08	0.28975664E 08	40.66	191	307.2
2C	Warehouses	0.29782990E 08	0.99470390E 07	33.40	113	128.4
3A	High Apartment Bldgs	0.19840174E 08	0.61742640E 07	31.12	83	85.5
3B	Low Apartment Bldgs	0.50407021E 07	0.11104842E 07	22.03	25	21.7
4A	Large Residences	0.13100544E 09	0.25009734E 08	19.09	487	564.9
4B	Small Residences	0.15114770E 09	0.22610410E 08	14.96	641	651.7
4C	Blighted Residences	0.31573722E 08	0.90349504E 07	28.62	190	136.1
	Total	0.65799016E 09	0.18219927E 09	27.69	2818	2837.1

TABLE 17

MEDIUM CITIES, 100K-500K

PERCENT ABOVE-GROUND FLOOR AREA

Code	Land Uses	Construction Types: WF	BR	ARC	JRC	HSF	LSF	Total
1A	Downtown Business Area	14.55	40.13	42.83	0.57	1.72	0.20	52.09
1B	Suburban Business Area	29.46	51.58	13.76	0.	4.34	0.87	3.12
2A	Light Manufacturing	22.38	50.90	17.22	0.06	6.20	3.24	8.97
2B	Heavy Manufacturing	9.48	45.58	34.33	0.88	8.28	1.46	8.27
2C	Warehouses	11.32	49.36	33.52	0.11	3.38	2.31	7.62
3A	High Apartment Bldgs	16.09	83.91	0.	0.	0.	0.	0.06
3B	Low Apartment Bldgs	38.21	61.14	0.65	0.	0.	0.	0.43
4A	Large Residences	36.84	55.20	7.10	0.04	0.77	0.06	8.23
4B	Small Residences	67.05	30.97	1.39	0.02	0.33	0.23	9.37
4C	Blighted Residences	71.55	18.02	9.46	0.	0.97	0	1.84
	Total	22.95	42.70	30.57	0.39	2.64	0.75	100.00

PERCENT GROUND AREA BUILT-UP

Code	Land Uses	Total Ground Area Surveyed (ft^2)	Total Ground Floor Area (ft^2)	Percent Built-Up	Block Counts: Actual	Norm.
1A	Downtown Business Area	0.70430457E 08	0.28524596E 08	40.50	365	303.7
1B	Suburban Business Area	0.17200699E 08	0.28755429E 07	16.72	58	74.2
2A	Light Manufacturing	0.24047806E 08	0.83317935E 07	34.65	51	103.7
2B	Heavy Manufacturing	0.25528360E 08	0.60878948E 07	23.85	39	110.1
2C	Warehouses	0.21376169E 08	0.55290706E 07	25.87	77	92.2
3A	High Apartment Bldgs	0.16684999E 06	0.25749998E 05	15.43	1	0.7
3B	Low Apartment Bldgs	0.18449999E 07	0.38914046E 06	21.09	8	8.0
4A	Large Residences	0.75826377E 08	0.87435490E 07	11.53	277	326.9
4B	Small Residences	0.88909018E 08	0.11102575E 08	12.49	487	383.4
4C	Blighted Residences	0.76817717E 07	0.16905510E 07	22.01	33	33.1
	Total	0.33301250E 09	0.73300460E 08	22.01	1396	1435.9

TABLE 18

SMALL CITIES, UNDER 100K

PERCENT ABOVE-GROUND FLOOR AREA

Code	Land Uses	Construction Types WF	BR	ARC	JRC	HSF	LSF	Total
1A	Downtown Business Area	14.13	57.37	22.07	0.10	6.00	0.33	55.45
1B	Suburban Business Area	46.73	37.65	15.11	0.	0.50	0.	1.46
2A	Light Manufacturing	38.88	37.10	22.01	0.	1.62	0.39	4.78
2B	Heavy Manufacturing	29.98	62.69	2.16	0.	4.75	0.42	4.19
2C	Warehouses	24.57	48.52	14.37	0.	8.27	4.27	4.14
3A	High Apartment Bldgs	0.75	0.	95.04	0.	4.21	0.	0.48
3B	Low Apartment Bldgs	33.77	63.53	2.70	0.	0.	0.	0.24
4A	Large Residences	41.76	41.73	14.65	0.	0.98	0.89	11.24
4B	Small Residences	81.07	17.62	1.06	0.	0.25	0.	17.21
4C	Blighted Residences	93.79	4.88	1.33	0.	0.	0.	0.80
	Total	32.13	46.69	16.51	0.05	4.13	0.50	100.00

PERCENT GROUND AREA BUILT-UP

Code	Land Uses	Total Ground Area Surveyed (ft^2)	Total Ground Floor Area (ft^2)	Percent Built-Up	Block Counts Actual	Norm.
1A	Downtown Business Area	0.75691399E 08	0.20966409E 08	27.70	354	328.4
1B	Suburban Business Area	0.32418581E 07	0.62202802E 06	19.19	19	14.0
2A	Light Manufacturing	0.77354269E 07	0.19311898E 07	24.97	19	33.4
2B	Heavy Manufacturing	0.63484120E 07	0.13474651E 07	21.23	10	27.4
2C	Warehouses	0.10422737E 08	0.18851636E 07	18.09	40	44.9
3A	High Apartment Bldgs	0.21469999E 06	0.68687490E 05	31.99	1	0.9
3B	Low Apartment Bldgs	0.38943248E 06	0.96562460E 05	24.80	1	1.7
4A	Large Residences	0.39430624E 08	0.55608295E 07	14.10	166	170.0
4B	Small Residences	0.89392119E 08	0.97506356E 07	10.91	451	385.4
4C	Blighted Residences	0.16093999E 07	0.26867490E 06	16.69	9	6.9
	Total	0.23447610E 09	0.42497644E 08	18.12	1070	1611.0

TABLE 19

NEW ENGLAND

PERCENT ABOVE-GROUND FLOOR AREA

Code	Land Uses	Construction Types: WF	BR	ARC	JRC	HSF	LSF	Total
1A	Downtown Business Area	5.73	46.00	46.77	0.	1.17	0.33	40.88
1B	Suburban Business Area	11.42	36.16	51.03	0.	0.31	1.07	10.32
2A	Light Manufacturing	24.34	60.05	12.36	0.	2.76	0.48	5.30
2B	Heavy Manufacturing	5.80	73.68	18.96	0.	1.56	0.	6.29
2C	Warehouses	15.62	45.18	31.66	0.	7.04	0.51	2.95
3A	High Apartment Bldgs	0.04	7.84	92.06	0.	0.07	0.	3.79
3B	Low Apartment Bldgs	0.	0.	0.	0.	0.	0.	0.
4A	Large Residences	51.93	40.39	6.63	0.	1.05	0.	6.20
4B	Small Residences	33.19	16.29	0.17	0.	0.14	0.21	9.89
4C	Blighted Residences	61.19	34.70	3.74	0.	0.37	0.	14.38
	Total	25.88	41.09	31.62	0.	1.10	0.31	100.00

PERCENT GROUND AREA BUILT-UP

Code	Land Uses	Total Ground Area Surveyed (ft^2)	Total Ground Floor Area (ft^2)	Percent Built-Up	Block Counts: Actual	Norm.
1A	Downtown Business Area	0.15076792E 08	0.67066946E 07	44.48	115	65.0
1B	Suburban Business Area	0.46385265E 07	0.16476324E 07	35.52	30	20.0
2A	Light Manufacturing	0.32410530E 07	0.18469731E 07	56.99	5	14.0
2B	Heavy Manufacturing	0.47789082E 07	0.16531184E 07	34.59	7	20.6
2C	Warehouses	0.37575201E 07	0.10556216E 07	28.09	14	16.2
3A	High Apartment Bldgs	0.26380882E 07	0.64140619E 06	24.31	11	11.4
3B	Low Apartment Bldgs	0.	0.	0.	0	0.
4A	Large Residences	0.12539276E 08	0.20099631E 07	16.03	47	54.1
4B	Small Residences	0.26478747E 08	0.35261517E 07	13.32	121	114.2
4C	Blighted Residences	0.15436346E 08	0.38173907E 07	24.73	102	66.6
	Total	0.88585[illegible]56E 08	0.22904951E 08	25.86	452	382.0

TABLE 20

MIDDLE ATLANTIC

PERCENT ABOVE-GROUND FLOOR AREA

Code	Land Uses	Construction Types WF	BR	ARC	JRC	HSF	LSF	Total
1A	Downtown Business Area	13.07	47.00	22.61	0.	17.03	0.29	30.10
1B	Suburban Business Area	55.80	23.13	2.94	0.	18.13	0.	2.02
2A	Light Manufacturing	5.62	63.49	9.88	0.	18.26	2.75	3.89
2B	Heavy Manufacturing	9.56	45.89	23.27	1.46	16.08	3.74	18.67
2C	Warehouses	23.12	65.04	10.07	0.	1.76	0.	1.10
3A	High Apartment Bldgs	8.67	80.28	10.34	0.	0.71	0.	1.61
3B	Low Apartment Bldgs	35.94	63.25	0.81	0.	0.	0.	1.28
4A	Large Residences	31.47	59.37	8.65	0.	0.51	0.	19.74
4B	Small Residences	64.70	32.71	1.75	0.	0.69	0.15	18.67
4C	Blighted Residences	61.78	35.88	0.56	0.	1.78	0.	2.93
	Total	28.01	47.34	13.93	0.27	9.52	0.92	100.00

PERCENT GROUND AREA BUILT-UP

Code	Land Uses	Total Ground Area Surveyed (ft^2)	Total Ground Floor Area (ft^2)	Percent Built-Up	Block Counts Actual	Norm.
1A	Downtown Business Area	0.11442601E 08	0.52313761E 07	45.72	55	49.3
1B	Suburban Business Area	0.29165994E 07	0.54705983E 06	18.76	9	12.6
2A	Light Manufacturing	0.33759820E 07	0.94153730E 06	27.89	11	14.6
2B	Heavy Manufacturing	0.17499009E 08	0.40525170E 07	23.16	26	75.5
2C	Warehouses	0.18754249E 07	0.33378118E 06	17.80	7	8.1
3A	High Apartment Bldgs	0.18382749E 07	0.15019897E 06	8.17	14	7.9
3B	Low Apartment Bldgs	0.10822500E 07	0.27906236E 06	25.79	4	4.7
4A	Large Residences	0.10518361E 08	0.28264172E 07	26.87	38	45.4
4B	Small Residences	0.24130831E 08	0.41860238E 07	17.35	107	104.0
4C	Blighted Residences	0.22622999E 07	0.65419973E 06	28.92	13	9.8
	Total	0.76941630E 08	0.19202173E 08	24.96	284	331.8

TABLE 21

UPPER SOUTH ATLANTIC

PERCENT ABOVE-GROUND FLOOR AREA

Code	Land Uses	Construction Types WF	BR	ARC	JRC	HSF	LSF	Total
1A	Downtown Business Area	5.38	50.67	43.38	0.	0.53	0.03	55.69
1B	Suburban Business Area	6.51	71.55	17.39	0.	2.95	1.59	5.38
2A	Light Manufacturing	18.21	36.37	42.19	0.	3.23	0.	4.61
2B	Heavy Manufacturing	6.86	19.01	70.82	0.	3.31	0.	3.38
2C	Warehouses	8.46	37.56	41.24	0.	8.49	4.25	2.44
3A	High Apartment Bldgs	0.29	51.03	48.68	0.	0.	0.	2.58
3B	Low Apartment Bldgs	0.	0.	0.	0.	0.	0.	0.
4A	Large Residences	13.85	69.00	16.59	0.	0.57	0.	13.10
4B	Small Residences	33.86	65.58	0.51	0.	0.04	0.	12.82
4C	Blighted Residences	0.	0.	0.	0.	0.	0.	0.
	Total	10.79	54.07	33.93	0.	1.00	0.21	100.00

PERCENT GROUND AREA BUILT-UP

Code	Land Uses	Total Ground Area Surveyed (ft^2)	Total Ground Floor Area (ft^2)	Percent Built-Up	Block Counts Actual	Norm.
1A	Downtown Business Area	0.26386635E 08	0.84105586E 07	31.87	146	113.8
1B	Suburban Business Area	0.53816590E 07	0.13936435E 07	25.90	22	23.2
2A	Light Manufacturing	0.63530953E 07	0.11619684E 07	18.29	15	27.4
2B	Heavy Manufacturing	0.24684876E 07	0.58792486E 06	23.82	6	10.6
2C	Warehouses	0.25023575E 07	0.58116856E 06	23.22	4	10.8
3A	High Apartment Bldgs	0.37617498E 06	0.23264994E 06	61.85	2	1.6
3B	Low Apartment Bldgs	0.	0.	0.	0	0.
4A	Large Residences	0.19605040E 08	0.32017021E 07	16.33	81	84.5
4B	Small Residences	0.36623953E 08	0.42911776E 07	11.72	181	157.9
4C	Blighted Residences	0.	0.	0.	0	0.
	Total	0.99697401E 08	0.19860793E 08	19.92	457	429.9

TABLE 22

LOWER SOUTH ATLANTIC

PERCENT ABOVE-GROUND FLOOR AREA

Code	Land Uses	Construction Types: WF	BR	ARC	JRC	HSF	LSF	Total
1A	Downtown Business Area	4.32	36.83	55.25	1.48	1.99	0.12	50.66
1B	Suburban Business Area	11.94	38.87	45.90	1.26	1.87	0.15	7.28
2A	Light Manufacturing	4.10	11.12	72.93	2.06	3.21	6.58	6.88
2B	Heavy Manufacturing	8.41	5.28	74.60	8.35	3.01	0.34	7.64
2C	Warehouses	18.78	54.92	17.34	3.16	1.68	4.12	4.78
3A	High Apartment Bldgs	1.05	24.56	74.38	0.	0.	0.	0.38
3B	Low Apartment Bldgs	23.33	48.70	25.83	0.	2.14	0.	1.83
4A	Large Residences	27.37	68.61	3.66	0.	0.36	0.	9.84
4B	Small Residences	21.59	74.39	3.78	0.	0.23	0.	9.48
4C	Blighted Residences	76.96	23.04	0.	0.	0.	0.	1.24
	Total	11.01	40.35	44.35	1.77	1.77	0.75	100.00

PERCENT GROUND AREA BUILT-UP

Code	Land Uses	Total Ground Area Surveyed (ft^2)	Total Ground Floor Area (ft^2)	Percent Built-Up	Block Counts: Actual	Block Counts: Norm.
1A	Downtown Business Area	0.21379159E 08	0.64487324E 07	30.16	92	92.2
1B	Suburban Business Area	0.75108767E 07	0.14243246E 07	18.96	28	32.4
2A	Light Manufacturing	0.21831374E 07	0.79114046E 06	36.24	10	9.4
2B	Heavy Manufacturing	0.17862687E 07	0.80050288E 06	44.81	8	7.7
2C	Warehouses	0.37463384E 07	0.89328580E 06	23.84	14	16.2
3A	High Apartment Bldgs	0.32447499E 06	0.50578119E 05	15.59	2	1.4
3B	Low Apartment Bldgs	0.20681699E 07	0.40278740E 06	19.48	10	8.9
4A	Large Residences	0.24268071E 08	0.25739804E 07	10.61	93	104.6
4B	Small Residences	0.23989736E 08	0.26127917E 07	10.89	58	103.4
4C	Blighted Residences	0.20870409E 07	0.33284367E 06	15.95	10	9.0
	Total	0.89343270E 08	0.16330967E 08	18.28	325	385.2

TABLE 23

EAST NORTH CENTRAL

PERCENT ABOVE-GROUND FLOOR AREA

Code	Land Uses	Construction Types						
		WF	BR	ARC	JRC	HSF	LSF	Total
1A	Downtown Business Area	0.79	28.48	69.07	0.55	1.04	0.07	50.51
1B	Suburban Business Area	11.91	78.23	9.70	0.	0.15	0.	2.88
2A	Light Manufacturing	3.13	60.30	31.04	0.	3.81	1.72	7.41
2B	Heavy Manufacturing	7.00	35.35	42.66	0.34	13.63	1.02	12.22
2C	Warehouses	3.15	50.94	37.46	0.	7.46	0.99	3.95
3A	High Apartment Bldgs	1.69	38.23	59.91	0.	0.16	0.02	6.44
3B	Low Apartment Bldgs	0.	0.	0.	0.	0.	0.	0.
4A	Large Residences	24.38	63.43	10.73	0.	1.46	0.	6.48
4B	Small Residences	54.83	42.54	1.91	0.	0.63	0.09	3.60
4C	Blighted Residences	9.66	57.28	32.46	0.	0.59	0.01	6.50
	Total	6.24	39.27	50.90	0.32	2.94	0.33	100.00

PERCENT GROUND AREA BUILT-UP

Code	Land Uses	Total Ground Area Surveyed (ft^2)	Total Ground Floor Area (ft^2)	Percent Built-Up	Block Counts	
					Actual	Norm.
1A	Downtown Business Area	0.39091061E 08	0.16363197E 08	41.86	219	168.6
1B	Suburban Business Area	0.84486776E 07	0.24297472E 07	28.76	40	36.4
2A	Light Manufacturing	0.11883995E 08	0.50785642E 07	42.73	29	51.2
2B	Heavy Manufacturing	0.17217890E 08	0.97402455E 07	56.57	30	74.2
2C	Warehouses	0.57583006E 07	0.32088379E 07	55.73	20	24.8
3A	High Apartment Bldgs	0.62583819E 07	0.23140226E 07	36.97	22	27.0
3B	Low Apartment Bldgs	0.	0.	0.	0	0.
4A	Large Residences	0.38175081E 08	0.66125171E 07	17.32	94	164.6
4B	Small Residences	0.36550494E 08	0.46541128E 07	12.73	129	157.6
4C	Blighted Residences	0.12958613E 08	0.43377732E 07	33.47	62	55.9
	Total	0.17634249E 09	0.54739016E 08	31.04	645	760.4

TABLE 24

EAST SOUTH CENTRAL

PERCENT ABOVE-GROUND FLOOR AREA

Code	Land Uses	Construction Types: WF	BR	ARC	JRC	HSF	LSF	Total
1A	Downtown Business Area	4.41	52.71	38.44	0.	3.63	0.81	45.97
1B	Suburban Business Area	10.03	60.90	7.24	0.	21.83	0.	5.31
2A	Light Manufacturing	8.90	44.05	41.12	0.	3.87	2.07	8.80
2B	Heavy Manufacturing	27.21	72.79	0.	0.	0.	0.	1.95
2C	Warehouses	7.10	44.44	44.56	0.	2.80	1.10	9.59
3A	High Apartment Bldgs	0.	0.	0.	0.	0.	0.	0.
3B	Low Apartment Bldgs	0.	0.	0.	0.	0.	0.	0.
4A	Large Residences	29.30	61.16	8.66	0.	0.69	0.	10.92
4B	Small Residences	65.26	33.19	0.86	0.	0.41	0.28	17.45
4C	Blighted Residences	0.	0.	0.	0.	0.	0.	0.
	Total	19.14	49.50	27.07	0.	3.58	0.71	100.00

PERCENT GROUND AREA BUILT-UP

Code	Land Uses	Total Ground Area Surveyed (ft^2)	Total Ground Floor Area (ft^2)	Percent Built-Up	Block Counts: Actual	Block Counts: Norm.
1A	Downtown Business Area	0.18502862E 08	0.67129216E 07	36.28	101	79.8
1B	Suburban Business Area	0.89608806E 07	0.14863621E 07	16.59	17	38.6
2A	Light Manufacturing	0.49352403E 07	0.14050869E 07	28.47	13	21.3
2B	Heavy Manufacturing	0.97057973E 06	0.33466867E 06	34.48	4	4.2
2C	Warehouses	0.33107498E 07	0.11881840E 07	35.89	15	14.3
3A	High Apartment Bldgs	0.	0.	0.	0	0.
3B	Low Apartment Bldgs	0.	0.	0.	0	0.
4A	Large Residences	0.16569200E 08	0.29153823E 07	17.60	59	71.4
4B	Small Residences	0.39035029E 08	0.56635729E 07	14.51	185	168.3
4C	Blighted Residences	0.	0.	0.	0	0.
	Total	0.92284541E 08	0.19706178E 08	21.35	394	397.9

TABLE 25

WEST NORTH CENTRAL

PERCENT ABOVE-GROUND FLOOR AREA

Code	Land Uses	Construction Types WF	BR	ARC	JRC	HSF	LSF	Total
1A	Downtown Business Area	14.97	37.14	47.42	0.02	0.44	0.02	65.26
1B	Suburban Business Area	6.99	93.01	0.	0.	0.	0.	0.23
2A	Light Manufacturing	11.65	59.75	26.41	0.06	1.13	1.00	3.78
2B	Heavy Manufacturing	25.99	35.17	34.13	0.	3.99	0.73	1.88
2C	Warehouses	4.22	58.02	36.64	0.12	0.66	0.34	9.16
3A	High Apartment Bldgs	6.33	52.58	40.34	0.	0.75	0.	2.01
3B	Low Apartment Bldgs	49.97	50.03	0.	0.	0.	0.	0.32
4A	Large Residences	43.30	44.50	11.86	0.	0.34	0.	8.28
4B	Small Residences	81.37	17.24	1.12	0.	0.28	0.	7.36
4C	Blighted Residences	7.00	52.42	39.89	0.	0.68	0.	1.73
	Total	21.08	39.76	38.50	0.03	0.54	0.09	100.00

PERCENT GROUND AREA BUILT-UP

Code	Land Uses	Total Ground Area Surveyed (ft^2)	Total Ground Floor Area (ft^2)	Percent Built-Up	Block Counts Actual	Block Counts Norm.
1A	Downtown Business Area	0.39538968E 08	0.18416901E 08	46.58	222	170.5
1B	Suburban Business Area	0.33102298E 06	0.11949998E 06	36.10	3	1.4
2A	Light Manufacturing	0.73139704E 07	0.16737164E 07	22.88	30	31.5
2B	Heavy Manufacturing	0.45169207E 07	0.78858726E 06	17.46	14	19.5
2C	Warehouses	0.81736746E 07	0.28378306E 07	34.72	51	35.2
3A	High Apartment Bldgs	0.24769199E 07	0.45502592E 06	18.37	14	10.7
3B	Low Apartment Bldgs	0.13266799E 07	0.20979371E 06	15.81	8	5.7
4A	Large Residences	0.38602795E 08	0.52284311E 07	13.54	171	166.4
4B	Small Residences	0.45631497E 08	0.54798173E 07	12.01	252	196.8
4C	Blighted Residences	0.37063059E 07	0.71705726E 06	19.35	16	16.0
	Total	0.15161875E 09	0.35926659E 08	23.70	781	653.7

TABLE 26

WEST SOUTH CENTRAL

PERCENT ABOVE-GROUND FLOOR AREA

Code	Land Uses	Construction Types: WF	BR	ARC	JRC	HSF	LSF	Total
1A	Downtown Business Area	3.46	22.71	68.05	0.	5.17	0.61	54.32
1B	Suburban Business Area	16.55	54.56	17.60	0.	9.19	2.09	1.17
2A	Light Manufacturing	38.20	23.42	20.50	0.	12.31	5.57	12.14
2B	Heavy Manufacturing	41.36	20.62	27.54	0.	2.39	8.08	7.99
2C	Warehouses	41.12	25.29	12.27	0.	13.11	8.22	3.86
3A	High Apartment Bldgs	0.	0.	0.	0.	0.	0.	0.
3B	Low Apartment Bldgs	34.22	57.74	0.	0.	0.	8.04	0.88
4A	Large Residences	25.43	50.46	13.08	0.	8.78	2.25	9.53
4B	Small Residences	59.95	36.58	2.82	0.	0.63	0.02	10.12
4C	Blighted Residences	0.	0.	0.	0.	0.	0.	0.
	Total	20.39	27.45	43.86	0.	6.01	2.28	100.00

PERCENT GROUND AREA BUILT-UP

Code	Land Uses	Total Ground Area Surveyed (ft^2)	Total Ground Floor Area (ft^2)	Percent Built-Up	Block Counts: Actual	Block Counts: Norm.
1A	Downtown Business Area	0.21003515E 08	0.73200371E 07	34.85	152	90.6
1B	Suburban Business Area	0.16659124E 07	0.41074991E 06	24.66	9	7.2
2A	Light Manufacturing	0.22322051E 08	0.33710015E 07	15.10	10	96.2
2B	Heavy Manufacturing	0.13134166E 08	0.22067865E 07	16.80	10	56.6
2C	Warehouses	0.99336652E 07	0.13623498E 07	13.71	32	42.8
3A	High Apartment Bldgs	0.	0.	0.	0	0.
3B	Low Apartment Bldgs	0.10697000E 07	0.24542494E 06	22.94	4	4.6
4A	Large Residences	0.19703937E 08	0.33177545E 07	16.84	61	85.0
4B	Small Residences	0.29700043E 08	0.37144518E 07	12.51	148	128.1
4C	Blighted Residences	0.	0.	0.	0	0.
	Total	0.11853299E 09	0.21948556E 08	18.52	426	511.1

TABLE 27

PACIFIC NORTHWEST

PERCENT ABOVE-GROUND FLOOR AREA

Code	Land Uses	Construction Types: WF	BR	ARC	JRC	HSF	LSF	Total
1A	Downtown Business Area	12.46	34.66	51.31	0.62	0.90	0.05	27.63
1B	Suburban Business Area	23.60	21.94	52.02	1.29	1.15	0.	4.68
2A	Light Manufacturing	34.88	24.11	36.88	0.19	3.67	0.26	7.81
2B	Heavy Manufacturing	40.91	20.61	36.65	0.98	0.38	0.47	38.30
2C	Warehouses	12.43	79.09	6.79	0.	0.	1.69	2.30
3A	High Apartment Bldgs	22.02	21.58	55.11	0.	1.30	0.	10.02
3B	Low Apartment Bldgs	42.29	44.36	13.35	0.	0.	0.	1.32
4A	Large Residences	73.57	16.67	9.74	0.01	0.	0.	3.48
4B	Small Residences	87.23	8.43	3.29	0.96	0.	0.09	3.95
4C	Blighted Residences	82.38	14.13	3.49	0.	0.	0.	0.51
	Total	32.41	25.93	39.87	0.66	0.87	0.26	100.00

PERCENT GROUND AREA BUILT-UP

Code	Land Uses	Total Ground Area Surveyed (ft^2)	Total Ground Floor Area (ft^2)	Percent Built-Up	Block Counts: Actual	Norm.
1A	Downtown Business Area	0.17436487E 08	0.59975452E 07	34.40	98	75.2
1B	Suburban Business Area	0.58268882E 07	0.20299918E 07	34.84	34	25.1
2A	Light Manufacturing	0.57046539E 07	0.28396860E 07	49.78	14	24.6
2B	Heavy Manufacturing	0.25607795E 08	0.11935111E 08	46.61	91	110.4
2C	Warehouses	0.36072592E 07	0.68878109E 06	19.09	12	15.6
3A	High Apartment Bldgs	0.55963796E 07	0.21434433E 07	38.30	14	24.1
3B	Low Apartment Bldgs	0.17283349E 07	0.45911870E 06	26.56	8	7.5
4A	Large Residences	0.98082424E 07	0.11831075E 07	12.06	43	42.3
4B	Small Residences	0.15388630E 08	0.17651651E 07	11.47	114	66.4
4C	Blighted Residences	0.15390999E 07	0.19760776E 06	12.84	8	6.6
	Total	0.92243767E 08	0.29239557E 08	31.70	436	397.7

TABLE 28

MOUNTAIN SOUTHWEST

PERCENT ABOVE-GROUND FLOOR AREA

Code	Land Uses	Construction Types WF	BR	ARC	JRC	HSF	LSF	Total
1A	Downtown Business Area	5.12	38.02	55.29	0.85	0.56	0.16	73.05
1B	Suburban Business Area	23.00	76.36	0.	0.	0.64	0.	0.85
2A	Light Manufacturing	3.45	36.84	58.32	0.	1.39	0.	2.49
2B	Heavy Manufacturing	7.35	53.45	23.48	0.	13.73	1.99	1.60
2C	Warehouses	2.60	63.86	18.17	0.	14.73	0.65	4.22
3A	High Apartment Bldgs	16.09	83.91	0.	0.	0.	0.	0.15
3B	Low Apartment Bldgs	0.	0.	0.	0.	0.	0.	0.
4A	Large Residences	19.39	66.45	11.52	0.	0.84	1.80	10.53
4B	Small Residences	32.30	65.45	1.94	0.02	0.18	0.11	7.12
4C	Blighted Residences	0.	0.	0.	0.	0.	0.	0.
	Total	8.62	44.67	44.33	0.62	1.39	0.37	100.00

PERCENT GROUND AREA BUILT-UP

Code	Land Uses	Total Ground Area Surveyed (ft^2)	Total Ground Floor Area (ft^2)	Percent Built-Up	Block Counts Actual	Norm.
1A	Downtown Business Area	0.52725119E 08	0.15929363E 08	30.21	245	227.3
1B	Suburban Business Area	0.27229593E 07	0.47887800E 06	17.59	21	11.7
2A	Light Manufacturing	0.16958516E 07	0.65846235E 06	38.83	5	7.3
2B	Heavy Manufacturing	0.30570126E 07	0.64345931E 06	21.05	4	13.2
2C	Warehouses	0.31851709E 07	0.11995623E 07	37.66	14	13.7
3A	High Apartment Bldgs	0.16684999E 06	0.25749998E 05	15.43	1	0.7
3B	Low Apartment Bldgs	0.	0.	0.	0	0.
4A	Large Residences	0.30135110E 08	0.47223044E 07	15.67	138	129.9
4B	Small Residences	0.30882693E 08	0.36487760E 07	11.81	188	133.2
4C	Blighted Residences	0.	0.	0.	0	0.
	Total	0.12[illegible]7076E 09	0.27306555E 08	21.92	616	537.1

TABLE 29

PACIFIC SOUTHWEST

PERCENT ABOVE-GROUND FLOOR AREA

Code	Land Uses	Construction Types: WF	BR	ARC	JRC	HSF	LSF	Total
1A	Downtown Business Area	4.62	39.50	54.29	0.70	0.61	0.29	37.18
1B	Suburban Business Area	50.20	25.53	23.23	0.	1.05	0.	1.38
2A	Light Manufacturing	20.19	16.07	54.22	4.86	1.17	3.49	17.67
2B	Heavy Manufacturing	16.13	13.19	54.13	5.27	7.13	4.14	14.04
2C	Warehouses	29.75	7.73	41.83	4.31	5.90	10.48	8.56
3A	High Apartment Bldgs	7.28	39.13	53.06	0.	0.53	0.	1.86
3B	Low Apartment Bldgs	0.	0.	0.	0.	0.	0.	0.
4A	Large Residences	80.41	9.43	9.87	0.20	0.08	0.01	9.67
4B	Small Residences	91.89	6.04	0.74	0.61	0.36	0.36	7.03
4C	Blighted Residences	68.38	5.95	25.29	0.	0.39	0.	2.59
	Total	26.94	22.61	43.92	2.29	2.01	2.23	100.00

PERCENT GROUND AREA BUILT-UP

Code	Land Uses	Total Ground Area Surveyed (ft^2)	Total Ground Floor Area (ft^2)	Percent Built-Up	Block Counts: Actual	Norm.
1A	Downtown Business Area	0.17826056E 08	0.75274415E 07	42.23	100	76.9
1B	Suburban Business Area	0.40480214E 07	0.69955610E 06	17.28	9	17.5
2A	Light Manufacturing	0.14819646E 08	0.50879376E 07	34.33	45	63.9
2B	Heavy Manufacturing	0.12096901E 08	0.[illegible]6681038E 07	30.32	40	52.2
2C	Warehouses	0.15731436E 08	0.40118711E 07	25.50	47	67.8
3A	High Apartment Bldgs	0.54617997E 06	0.25562650E 06	46.80	5	2.4
3B	Low Apartment Bldgs	0.	0.	0.	0	0.
4A	Large Residences	0.26337340E 08	0.47225550E 07	17.93	105	113.6
4B	Small Residences	0.21037208E 08	0.39215829E 07	18.64	96	90.7
4C	Blighted Residences	0.28751908E 07	0.93730444E 06	32.60	21	12.4
	Total	0.11531797E 09	0.30831978E 08	26.74	468	497.2

TABLE 30

THE UNITED STATES

PERCENT ABOVE-GROUND FLOOR AREA

Code	Land Uses	Construction Types WF	BR	ARC	JRC	HSF	LSF	Total
1A	Downtown Business Area	6.08	36.81	54.79	0.38	1.76	0.18	49.84
1B	Suburban Business Area	15.30	51.45	29.14	0.25	3.34	0.53	3.35
2A	Light Manufacturing	15.94	39.56	36.88	1.15	4.13	2.36	7.23
2B	Heavy Manufacturing	19.86	30.28	39.35	1.40	7.37	1.73	10.33
2C	Warehouses	11.65	45.59	33.78	0.82	5.31	2.84	4.91
3A	High Apartment Bldgs	6.62	34.77	58.14	0.	0.46	0.01	3.49
3B	Low Apartment Bldgs	36.46	51.97	9.84	0.	0.48	1.25	0.33
4A	Large Residences	35.04	52.73	10.67	0.02	1.22	0.32	8.80
4B	Small Residences	62.23	35.75	1.45	0.08	0.36	0.12	8.05
4C	Blighted Residences	34.60	44.25	20.60	0.	0.54	0.00	3.65
	Total	17.03	38.82	40.55	0.48	2.48	0.64	100.00

PERCENT GROUND AREA BUILT-UP

Code	Land Uses	Total Ground Area Surveyed (ft^2)	Total Ground Floor Area (ft^2)	Percent Built-Up	Block Counts Actual	Norm.
1A	Downtown Business Area	0.28040924E 09	0.10506476E 09	37.47	1545	1209.1
1B	Suburban Business Area	0.52452023E 08	0.12667445E 08	24.15	222	226.2
2A	Light Manufacturing	0.83828669E 08	0.24856073E 08	29.65	187	361.5
2B	Heavy Manufacturing	0.10313393E 09	0.36411024E 08	35.30	240	444.7
2C	Warehouses	0.61581895E 08	0.17361273E 08	28.19	230	265.5
3A	High Apartment Bldgs	0.20221723E 08	0.62687013E 07	31.00	85	87.2
3B	Low Apartment Bldgs	0.72751344E 07	0.15961871E 07	21.94	34	31.4
4A	Large Residences	0.24626243E 09	0.39314112E 08	15.96	930	1061.8
4B	Small Residences	0.32944883E 09	0.43463621E 08	13.19	1579	1420.5
4C	Blighted Residences	0.40864893E 08	0.10994176E 08	26.90	232	176.2
	Total	0.12254787E 10	0.29799737E 09	24.[illegible]2	5284	5284.0

CHAPTER VI

STATISTICAL ANALYSIS OF THE BUILDING-CONSTRUCTION SUMMARIES

A. INTRODUCTION

A most important part of the building-construction survey is the data analysis and interpretative phase of the project. All of the planning and work devoted to the survey now results in several tables and conclusions upon which the next phase of the project must build. Hence, to understand the analytical results and their interpretation, one must refer to the planning and data-collection phases of the project.

The selection of geographic regions and the definition of urban-area sizes were discussed in Chapter II. The hypothesis was originally made that building size and construction varied widely throughout the contiguous United States. This variation was attributed to (1) geographic-climatic differences, and (2) urban-area size. Consequently, the contiguous states were divided into eleven geographic regions, and the urban areas were divided according to a Bureau of the Census definition into four area sizes. For reference, the geographic regions and urban-area sizes are listed below. In parentheses following each is its abbreviation used in other tables in this chapter.

Geographic Regions

(1) New England (NE)

(2) Middle Atlantic (MA)

(3) Upper South Atlantic (USA)

(4) Lower South Atlantic (LSA)

(5) East North Central (ENC)

(6) East South Central (ESC)

(7) West North Central (WNC)

(8) West South Central (WSC)

(9) Pacific Northwest (PNW)

(10) Mountain Southwest (MSW)

(11) Pacific Southwest (PSW)

Urban-Area Sizes

(1) Large (over 500,000 population)

(2) Medium (100,000 to 500,000 population)

(3) Small (under 100,000 population)

Urban-area size (3) includes both small and very small urban areas as defined in Chapter II.

B. STATISTICAL ANALYSIS BASED ON CONSTRUCTION DATA

Cities were then selected from each geographic-region, urban-area-size combination. Hence, any data obtained for these cities can immediately and naturally be arranged in a two-dimensional (two-way) layout. Table 31 illustrates this layout and identifies the urban areas in each geographic-region, urban-area-size combination. The statistical analysis of data

TABLE 31

URBAN-AREA LAYOUT

Urban Area Size	Geographic Region										
	NE	MA	USA	LSA	ENC	WNC	ESC	WSC	MSW	PNW	PSW
Large	Boston	Jersey City	Washington	Miami	Chicago	Minneapolis	Louisville	Houston	Denver	Portland	San Francisco
		Brooklyn				St. Louis					
Medium	Waterbury	Erie	Wilmington	Columbia	Lansing	Omaha	Mobile	Little Rock	Tucson	Tacoma	Fresno
						Wichita			Albuquerque		
Small	Lewiston	Rome	High Point	Albany	Green Bay	Rapid City	Huntsville	Abilene	Las Vegas	Great Falls	Riverside
			Weirton			Minot	Johnson City	Laredo	Las Cruces	Bend	
						Winfield	Clarksdale		Brigham City		

arranged in such a layout involves the computation of row and column differences and the comparison of these differences with the experimental errors. When row and/or column differences cannot be explained on the basis of experimental errors, the differences must be attributed to some other cause and are said to be statistically significant.

Land uses were discussed in Chapter III. For reference within this chapter, the ten land uses are listed below.

Land Uses

(1) Downtown

(2) Suburban Shopping

(3) Light Manufacturing

(4) Heavy Manufacturing

(5) Warehouses

(6) High Apartment Buildings (more than two floors)

(7) Low Apartment Buildings (one or two floors)

(8) Large Residences (greater than 2000 sq ft)

(9) Small Residences (less than 2000 sq ft)

(10) Blighted Residences

The hypothesis was originally made that building size and construction varied widely with land use. The truth of this hypothesis was so obvious that no statistical evaluation of differences due to land use were planned. However,

during the statistical-analysis phase of this project, land-use differences were tested. An indication of homogeneous construction for different land uses did occur among manufacturing and warehouse areas. This result is utilized in the list of typical areas to be developed.

The data collected can thus be arranged into ten tables similar to Table 31, i.e., one table for each land use. Within each geographic-region, urban-area-size category for any particular land use would be a list of six numbers for each urban area, representing the percent construction for each building type permitted. For reference within this chapter, the six construction types are listed below. (These construction types and the Sanborn categories assigned to each were discussed in Chapter IV.) In the parentheses following the construction types listed below is an abbreviation used in other tables in this chapter. However, when all six construction percentages are recorded, as in Table 32, no identification is given; it will be assumed that they are given in the order listed below.

<u>Construction Types</u>

(1) Wood Frame (WF)

(2) Brick (BR)

(3) American Reinforced Concrete (ARC)

(4) Japanese Reinforced Concrete (JRC)

(5) Heavy Steel Frame (HSF)

(6) Light Steel Frame (LSF)

TABLE 32

LAYOUT FOR DOWNTOWN BUSINESS AREAS

Urban Area Size	Geographic Region													
	NE	MA	USA		LSA	ENC	WNC			ESC			WSC	
Large	4.46	25.42	1.48		2.72	0.56	4.22	0.76		0.48			3.10	
	43.03	45.05	53.77		14.34	26.30	51.93	35.59		41.55			12.62	
	50.92	25.28	44.63		79.51	72.04	43.26	62.91		55.20			77.06	
	0.00	0.00	0.00		2.64	0.45	0.00	0.06		0.00			0.00	
	1.23	4.16	0.11		0.70	0.59	0.58	0.67		2.61			6.48	
	0.37	0.09	0.01		0.08	0.07	0.01	0.00		0.17			0.74	
Medium	4.96	2.29	0.98		3.01	3.25	31.26	0.60		4.40			1.36	
	70.48	48.81	29.61		65.21	47.89	23.12	48.80		58.49			41.93	
	23.40	42.25	67.04		28.76	39.65	45.42	50.60		29.51			55.35	
	0.00	0.00	0.00		0.00	2.30	0.00	0.00		0.00			0.00	
	0.90	6.60	2.12		2.95	6.74	0.17	0.00		6.03			1.08	
	0.26	0.05	0.25		0.07	0.17	0.04	0.00		1.56			0.27	
Small	21.32	7.44	12.57	58.97	12.74	2.84	15.21	11.99	9.88	20.90	3.16	15.06	5.88	10.58
	51.03	47.81	58.11	36.12	65.79	54.73	63.71	53.06	76.63	64.57	91.13	76.82	47.23	58.03
	26.82	6.80	27.34	4.92	16.19	39.15	20.27	34.95	5.55	4.98	5.71	4.36	44.06	26.56
	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.82	37.30	1.67	0.00	4.90	3.29	0.36	0.00	7.93	5.69	0.00	3.76	2.26	4.84
	0.00	0.65	0.00	0.00	0.38	0.00	0.00	0.00	0.00	3.86	0.00	0.00	0.58	0.00

TABLE 32 (Continued)

LAYOUT FOR DOWNTOWN BUSINESS AREAS

Urban Area Size	Geographic Region					
	MSW			PNW		PSW
Large	1.87			1.46		3.74
	32.08			17.18		32.16
	64.90			79.94		62.52
	0.41			0.35		0.87
	0.58			0.98		0.49
	0.16			0.09		0.21
Medium	2.79	5.56		19.62		5.01
	50.18	50.54		39.59		56.43
	46.14	35.76		39.07		35.90
	0.00	6.64		0.93		0.00
	0.88	1.25		0.78		1.55
	0.00	0.26		0.01		1.10
Small	21.59	7.62	10.21	2.68	26.75	9.55
	49.16	78.52	89.42	57.80	58.29	67.47
	29.07	8.42	0.17	37.76	14.61	22.30
	0.01	5.27	0.00	0.00	0.00	0.29
	0.00	0.00	0.20	1.77	0.00	0.39
	0.18	0.17	0.00	0.00	0.36	0.00

Table 32 illustrates the general form of the ten data tables and specifically presents the data for land-use 1a, downtown business areas. Since no downtown business area was observed in the Sanborn volumes ordered for Brooklyn, New York, the construction percentages (all zero) were omitted for this urban area.

The group in each column corresponds to the urban area shown in Table 31 for that particular geographic-region, urban-area-size combination. For example, the West-North-Central box with the large urban areas Minneapolis and St. Louis is illustrated in Table 33.

TABLE 33

LARGE WEST-NORTH-CENTRAL DOWNTOWN BUSINESS AREAS

Construction Type	Percent Construction	
	Minneapolis	St. Louis
WF	4.22	0.76
BR	51.93	35.59
ARC	43.26	62.91
JRC	0.00	0.06
HSF	0.58	0.67
LSF	0.01	0.00

With this background discussion, it is now possible to state simply the type of statistical problem, and thus the analytical technique required. For the purely statistically-minded readers, the data can be arranged into basic two-way, nonorthogonal, multivariate layouts. The layouts are

two-way because of the geographic-region and urban-area-size categories; they are nonorthogonal because not all of the geographic-region, urban-area-size categories have the same number of urban areas assigned to them; and they are multivariate because for each urban area there is a six-element vector representing the building-construction types permitted. The analytical technique is thus determined and is described in more detail in Appendix C.

As the urban areas were examined, it soon became evident that not all land uses could be found in each urban area. Reasons are easy to find. For example, very small towns such as Winfield, Kansas, and Bend, Oregon, simply do not have suburban shopping centers or blighted residential areas. As a result, there appear many empty cells in some of the land-use tables. Entire geographic regions are not represented for some land uses.

It also became evident that not all construction types would be represented in each land use. Reasons are again easy to find. For example, residential areas seldom, if ever, contain Japanese reinforced-concrete or heavy-steel-frame construction. When they do, the construction is some non-residential building such as a public or commercial structure. Sometimes the amount of such construction is so small that for purely mathematical reasons it must be excluded from the analytical calculations. Hence, as one studies the data for the ten land uses, the dimensions vary for the two-way, nonorthogonal, multivariate layouts.

An algebraic presentation of the least-squares technique required for the analysis of such multivariate data arrays is included in Appendix C. Based on the least-squares principles, a computer program was developed to perform these calculations. Results from these analyses are presented in Table 34.

The test statistic, U, presented in this table is a multivariate test of the significance of geographic regions and urban-area sizes as an explanation of the observed variability in the construction data. Two further aspects must also be noted. First, the test statistic, U, in multivariate analysis has been defined so that a significant observed U is <u>less</u> than the standard U. This test is exactly opposite to most common statistical tests. Second, the conclusions from these analyses are defined as "statistical conclusions." Significance simply means that there is less than one chance in twenty that the observed U occurred without assignable cause, i.e., due only to the experimental or residual error. This result in no way implies that there is a difference in casualty production.

C. DISCUSSION OF STATISTICAL RESULTS USING CONSTRUCTION DATA

Next in the analytical sequence is a review of the significant statistical conclusions indicated by the analytical computations. The <u>downtown</u> construction data indicate a dependence on urban-area size. From the urban area-size summaries, the important percentages for downtown construction are shown in Table 35.

TABLE 34

RESULTS FROM STATISTICAL ANALYSIS USING CONSTRUCTION DATA

Land Use	Size or Region	Obs. U.	Std. U.	Statistical Conclusion
Downtown	Size	0.268	0.502	Significant
	Region	0.106	0.101	Not significant
Suburban Shopping	Size	0.207	0.099	Not significant
	Region	0.0025	0.0029	Might be significant
Light Manufacturing	Size	0.312	0.275	Not significant
	Region	0.030	0.021	Not significant
Heavy Manufacturing	Size	0.222	0.229	Significant
	Region	0.018	0.0014	Not significant
Warehouses	Size	0.349	0.179	Not significant
	Region	0.0082	0.0083	Might be significant
High Apartment Buildings (more than two floors)	Size	Insufficient data observed		
	Region			
Low Apartment Buildings (one or two floors)	Size	Insufficient data observed		
	Region			
Large Residences (greater than 2000 sq ft)	Size	0.616	0.477	Not significant
	Region	0.071	0.088	Significant
Small Residences (less than 2000 sq ft)	Size	0.325	0.502	Significant
	Region	0.087	0.101	Significant
Blighted Residences	Size	0.194	0.024	Not significant
	Region	0.019	0.0037	Not significant

TABLE 35

CONSTRUCTION PERCENTAGES FOR DOWNTOWN AREAS

Construction Type	Urban-Area Size Large	Medium	Small
WF	2.32	14.55	14.13
BR	32.75	40.13	57.37
ARC	63.27	42.83	22.07

Two conclusions are immediately evident. Wood frame (WF) percentages probably begin close to 0 percent for our largest urban areas and rise to about 14 percent for medium-size cities, where the percentage levels off and remains constant. Intuitively, one might expect a further rise for very small urban areas. However, our data table has insufficient size categories to demonstrate that such a rise does or does not occur. The second item to note is the very strong linear dependence of brick (BR) and American reinforced-concrete (ARC) percentages on area size. A little reflection leads one to see that reinforced concrete will be used more in large urban areas than in small urban areas, and conversely for brick. Hence, the statistically significant effects indicated by the analytical computations are easily seen.

The construction data for suburban shopping areas show slight differences based on geographic regions. When the regional summaries were examined, patterns were simply not evident. The rather large variability exhibited by these data, shown in Table 36, may be due to small samples and

TABLE 36

CONSTRUCTION PERCENTAGES FOR SUBURBAN SHOPPING AREAS

Construction Type	Geographic Region										
	NE	MA	USA	LSA	ENC	ESC	WNC	WSC	PNW	MSW	PSW
WF	11.42	55.80	6.51	11.94	11.91	10.03	6.99	16.55	23.60	23.00	50.20
BR	36.16	23.13	71.55	38.87	78.23	60.90	93.01	54.56	21.94	76.36	25.53
ARC	51.03	2.94	17.39	45.90	9.70	7.24	0.00	17.60	52.02	0.00	23.23
Blocks Observed	30	9	22	28	40	17	3	9	34	21	9

hence may even represent the choice of materials for a single shopping area. While this aspect has not and perhaps could not be determined, the small sample sizes for some geographic regions may be sufficient reason to reject the indecisive test conclusions.

The construction of light manufacturing buildings is independent of both urban-area size and geographic region.

However, the construction of heavy manufacturing buildings seems dependent on urban-area size. A review of these data (Table 37) from the urban-area-size summaries reveals a pattern similar to that observed for downtown areas, except that the percentages for wood-frame (WF) behave very strangely. The trend in both brick (BR) and American reinforced concrete (ARC) seems statistically significant though.

TABLE 37

CONSTRUCTION PERCENTAGES FOR HEAVY MANUFACTURING AREAS

Construction Type	Urban-Area Size		
	Large	Medium	Small
WF	21.46	9.48	29.98
BR	25.73	45.58	62.69
ARC	42.08	34.33	2.16

The analysis of construction data for warehouse areas indicates some slight dependence on geographic region. An examination of the

geographic-region summaries (Table 38) reveals no discernible patterns or subgroupings. However, the rather small number of blocks observed in the Middle-Atlantic and Upper-South-Atlantic regions may be sufficient to cause the very slight indicated significance and to give reason for rejection of the indecisive test conclusions.

Insufficient data were observed for both high and low apartment buildings to be able to reach any statistical conclusions.

Table 39 presents the important data for large residences. The most interesting feature of these data concerns the rather obvious groupings present. Seven contiguous geographic regions; namely, the Middle Atlantic, the Upper and Lower South Atlantic, the East North Central, the East and West South Central, and the Mountain Southwest are all very similar, while the Pacific Northwest and Southwest are also very similar. Computations similar to those required for Table 34 show that the first group of seven regions is homogeneous, i.e., the differences are not significant, but the Pacific Northwest and Southwest are significantly different. Hence, the number of regions is effectively reduced from eleven to five for large residences.

A review of the important construction percentages for small residences classified by urban-area size, shown in Table 40, shows definite trends similar to those already observed for downtown and heavy manufacturing areas.

TABLE 38

CONSTRUCTION PERCENTAGES FOR WAREHOUSE AREAS

Construction Type	Geographic Region										
	NE	MA	USA	LSA	ENC	ESC	WNC	WSC	PNW	MSW	PSW
WF	15.62	23.12	8.46	18.78	3.15	7.10	4.22	41.12	12.43	2.60	29.75
BR	45.18	65.04	37.56	54.92	50.94	44.44	58.02	25.29	79.09	63.86	7.73
ARC	31.66	10.07	41.24	17.34	37.46	44.56	36.64	12.27	6.79	18.17	41.83
HSF	7.04	1.76	8.49	1.68	7.46	2.80	0.66	13.11	0.00	14.73	5.90
LSF	0.51	0.00	4.25	4.12	0.99	1.10	0.34	8.22	1.69	0.65	10.48
Blocks Observed	14	7	4	14	20	15	51	32	12	14	47

TABLE 39

CONSTRUCTION PERCENTAGES FOR LARGE RESIDENCES

Construction Type	Geographic Region										
	NE	MA	USA	LSA	ENC	ESC	WNC	WSC	PNW	MSW	PSW
WF	51.93	31.47	13.85	27.37	24.38	29.30	43.30	25.43	73.57	19.39	80.41
BR	40.39	59.37	69.00	68.61	63.43	61.16	44.50	50.46	16.67	66.45	9.43

TABLE 40

CONSTRUCTION PERCENTAGES FOR SMALL RESIDENCES BY URBAN-AREA SIZE

Construction Type	Urban-Area Size		
	Large	Medium	Small
WF	53.79	67.05	81.07
BR	43.94	30.97	17.62

Hence, the statistically significant effects indicated by the analytical computations are easily seen.

Turning next to the geographic regional summaries for small residences, shown in Table 41, the sharp pattern discernible for large residences is not apparent. Due to this result and the slight nature of the significance, these test conclusions were rejected.

The construction of blighted residences is independent of both urban-area size and geographic region.

In summary, technical problems in the observation technique could account for the regional differences observed in the suburban-shopping and warehouse construction. However, very real differences exist in downtown, heavy manufacturing, and small residential areas due to urban-area size. Statistically significant differences also exist in both large and small residential areas due to geographic regions, but the number of regions can be substantially reduced for the large residential areas. The test conclusions were rejected for the small residential areas for the reasons described above.

TABLE 41

CONSTRUCTION PERCENTAGES FOR SMALL RESIDENCES BY GEOGRAPHIC REGION

Construction Type	Geographic Region										
	NE	MA	USA	LSA	ENC	ESC	WNC	WSC	PNW	MSW	PSW
WF	83.19	64.70	33.86	21.59	54.83	65.26	81.37	59.95	87.23	32.30	91.89
BR	16.29	32.71	65.58	74.39	42.54	33.19	17.24	36.58	8.43	65.45	6.04

Table 42 presents a summary of the resulting typical areas based on construction which are required to represent the various land uses throughout the United States.

D. STATISTICAL ANALYSIS BASED ON CASUALTY CURVES

One should note that the previous statistical tests were based on the construction percentages and not on values from the casualty curves. Thus, although the construction percentages were found to be statistically significant for the cases listed in Table 42, this result in no way implies that there is a difference in casualty production among all of these cases.

Therefore, statistical tests were again made using values from both low (10% level) and high (90% level) points on the 1- and 25-Mt mortality curves. Based on the least-squares principles, a computer program was developed to perform these calculations. Results from these analyses are presented in Table 43.

Two aspects of Table 43 should be noted. First, the test statistic, F, in univariate analysis has been defined so that a significant observed F is greater than the standard F. Second, the conclusions from these analyses are defined as "statistical conclusions." Significance simply means that there is less than one chance in twenty that the observed F occurred without assignable cause, i.e., due only to the experimental or residual error.

TABLE 42

TYPICAL URBAN AREAS BASED ON CONSTRUCTION

Category	Percent Construction by Type					
	WF	BR	ARC	JRC	HSF	LSF
1. Downtown						
a. Large Cities	2	33	63	1	1	0
b. Medium Cities	14	40	43	1	2	0
c. Small Cities	14	58	22	0	6	0
2. Suburban Shopping	15	52	29	0	3	1
3. Light Manufacturing	16	40	37	1	4	2
4. Heavy Manufacturing						
a. Large Cities	21	26	42	2	7	2
b. Medium Cities	10	46	34	1	8	1
c. Small Cities	30	63	2	0	5	0
5. Warehouses	12	45	34	1	5	3
6. High Apartment Bldgs.	7	35	58	0	0	0
7. Low Apartment Bldgs.	36	52	10	0	1	1
8. Large Residences						
a. Eastern Composite*	30	57	11	0	2	0
b. New England	52	40	7	0	1	0
c. West North Central	43	45	12	0	0	0
d. Pacific Northwest	73	17	10	0	0	0
e. Pacific Southwest	80	10	10	0	0	0
9. Small Residences						
a. Large Cities	54	44	2	0	0	0
b. Medium Cities	67	31	2	0	0	0
c. Small Cities	81	18	1	0	0	0
10. Blighted Residences	35	44	21	0	0	0

* Composed of Middle Atlantic, Upper South Atlantic, Lower South Atlantic, East North Central, East South Central, West South Central, and Mountain Southwest.

TABLE 43

RESULTS FROM STATISTICAL ANALYSIS USING CASUALTY CURVES

Land Use‡	Theoretical Variance Ratio		Estimated Variance Ratio							
			1 Mt (high)		1 Mt (low)		25 Mt (high)		25 Mt (low)	
	Size	Region	Size	Region	Size	Region	Size	Region	Size	Region
Downtown	3.2948	2.1428	22.96*	1.097	18.91*	0.8760	23.00*	1.115	18.14*	0.8152
Suburban Shopping	3.9823	2.8536	2.211	0.7863	1.904	0.7441	2.251	0.8054	1.758	0.6564
Light Manufacturing	3.5546	2.4117	5.276*	0.4194	6.049*	0.4087	5.237*	0.4061	6.086*	0.3700
Heavy Manufacturing	3.6337	2.4935	11.36*	1.623	7.711*	0.8528	11.19*	1.617	7.814*	0.9471
Warehouses	3.7389	2.6021	8.539*	2.201	8.682*	2.344	8.393*	2.184	8.482*	2.234
Large Residences	3.3277	2.1768	0.04774	0.2662	0.05407	0.3312	0.04960	0.2672	0.05426	0.3266
Small Residences	3.2948	2.1428	6.185*	2.028	6.535*	3.341*	5.983*	1.897	6.581*	3.340*
Blighted Residences	5.1433	4.2839	0.01698	1.957	0.1282	2.017	0.01458	1.959	0.1247	2.013

* These values are significant in a statistical sense.

‡ High and low apartment buildings were omitted since insufficient data were observed.

E. DISCUSSION OF STATISTICAL RESULTS USING CASUALTY CURVES

A review of the significant statistical conclusions indicated by the results listed in Table 43 is the next item of interest. The statistical tests on the downtown casualty data indicate a dependence on urban-area size, as did the earlier tests on the construction data. It would thus seem that three typical areas representing urban-area size will be required for downtown urban areas.

The tests on casualty data for suburban shopping centers still do not indicate any dependence on either urban-area size or geographic region. It thus appears that one typical area will represent this land-use category throughout the United States.

In contrast to the earlier tests on construction data which did not indicate any dependence on either urban-area size or geographic region for light manufacturing areas, the tests on casualty data indicate a dependence on urban-area size. However, it is felt that the significance should show up in both tests before additional typical areas are added to the list. In addition, this category appears to be a little-used one, as compared to the other categories, and therefore needs less representation. Thus, one typical area will be used to represent this land-use category throughout the United States.

The tests on casualty data for heavy manufacturing areas still indicate a definite dependence on urban-area size. Thus, three typical areas

representing the various urban-area sizes will be required for this land-use category.

For warehouse areas the earlier statistical tests indicated that only one typical area would be required, whereas the tests on casualty data indicate a dependence on urban-area size. (The results are thus similar to those obtained for light manufacturing areas.) Since these two tests did not substantiate each other and since warehouses are a relatively little-used category, it is felt that one typical area will be sufficient to represent this land-use category throughout the United States.

Insufficient data were observed for both high and low apartment buildings to reach any statistical conclusions about their dependence on urban-area size or geographic region. Therefore, one typical area will be used to represent each of these land-use categories throughout the United States.

The statistical tests on casualty data for large residences do not indicate any dependence on either urban-area size or geographic region. This result is in contrast to the previous test which indicated a dependence on geographic region. It is felt that the dependence on geographic region should be ignored since the significance should show up in both tests before additional typical areas are added to the list. Thus, one typical area will be used to represent this land-use category throughout the United States.

For small residences the statistical tests on casualty data indicate a definite dependence on urban-area size, but the tests show significance

for only half the cases (10% level on casualty curves) for geographic regions. Due to this result and the fact that no sharp pattern was discernible among geographic regions when examining the earlier tests on construction data, it is felt that only the dependence on urban-area size should be considered. Thus, three typical areas will be used to represent this land-use category.

As before, the statistical tests on casualty data for blighted residences still do not indicate any dependence on either urban-area size or geographic region. Therefore, one typical area will be used to represent this land-use category throughout the United States.

F. TYPICAL AREAS FOR CASUALTY CURVES

It should be pointed out that anyone interested in debris or fire studies on a national scale would probably be interested in the list of typical areas (based on construction) given in Table 42. However, for casualty curves to be used on a national basis, one can still do more consolidating beyond those typical areas described in the preceding section.

Table 44 presents the list of typical areas which will be used in computing the set of casualty curves. (The only addition to be made is that for the population percentage outside, to be discussed in the next chapter.) In several cases the construction percentages by type were so similar for different land-use categories that the casualty curves would have been identical; thus, these land-use categories were combined.

TABLE 44

TYPICAL URBAN AREAS FOR CASUALTY CURVES
(No Population Outside)

Category	Percent Construction by Type					
	WF	BR	ARC	JRC	HSF	LSF
1. Downtown in Large Cities and High Apartment Bldgs.	4	34	60	1	1	0
2. Downtown in Medium Cities	14	40	43	1	2	0
3. Downtown in Small Cities and Suburban Shopping	14	55	25	0	5	1
4. Light Manufacturing, Heavy Manufacturing in Medium Cities, and Warehouses	13	44	35	1	5	2
5. Heavy Manufacturing in Large Cities	21	26	42	2	7	2
6. Heavy Manufacturing in Small Cities	30	63	2	0	5	0
7. Low Apartment Bldgs. and Large Residences	36	53	10	0	1	0
8. Small Residences in Large Cities	54	44	2	0	0	0
9. Small Residences in Medium Cities	67	31	2	0	0	0
10. Small Residences in Small Cities	81	18	1	0	0	0

As can be seen from Table 42, "downtown in large cities" and "high apartment buildings" are quite similar in construction percentages, as are "downtown in small cities" and "suburban shopping centers." It should also be noted that there are logical reasons for these similarities. Likewise, "light manufacturing", "heavy manufacturing in medium cities", and "warehouses" show such striking similarities in construction percentages that they were combined into one group as shown in Table 44. Finally, "low apartment buildings" and "large residences" were also combined for the same reasons.

"Blighted residences" were omitted from the list of typical areas given in Table 44 because of the high percentage of American reinforced-concrete construction indicated in Table 42. This value is high because a large fraction of the data came from the slum areas of large cities, similar to Harlem. It is not felt to be typical of the country as a whole. Blighted areas can be represented by "high apartment buildings" or "small residences", as the case may be.

As a result, the list of typical areas has been pared to ten, which still produces a sizeable number of casualty curves.

CHAPTER VII

POPULATION PERCENTAGE OUTSIDE STRUCTURES

A. PERCENTAGE OF POPULATION OUTSIDE STRUCTURES

To determine the percentage of the population which is outside structures in a city or urban area, use was made of the Operations Research Incorporated Technical Report 210 entitled Study of Tactical Movement Concepts and Procedures for Civil Defense Planning (Ref. 3). From this report it was evident that at least a crude formula could be derived which would predict the population outside structures in a city. This equation was derived from the population breakdown presented in Tables C. 3, C. 5, and C. 11 of Ref. 3. The equation takes into account the changes in population as a function of the time of day. The population distribution given in Table C. 5 of Ref. 3 was for times of 11:00 a. m., 5:30 p. m., and 2:30 a. m.

The equation utilizes the population breakdow[illegible] the city census-tract reports which were compiled by the U. S. [illegible] f Commerce for 1960. Accordingly, the employed population w[illegible] vided into seven applicable categories as follows: mining, construction, manufacturing, railroad and rail-express service, other transportation, communications (also utilities and sanitation), and other work (not reported in one of the above categories). Although the total work force varies according to the time of day, the relative percentages of people employed in each of the

above categories remain fixed. Also, the fraction of the people in each employment category who are outside structures (Table C. 3 of Ref. 3) was assumed to remain constant with time.

From the census-data population breakdown, the total population of a city can be divided into three mutually-exclusive broad divisions. (At any given time no one person can be in more than one division.) These three broad divisions are employed population, school population, and free population (those not employed or in school at the given time). The breakdown of the employed population division was described above.

For any given case the actual employed, school, and free population at one of the stated times was determined from use of the census data and Table C. 5 of Ref. 3. The percentage of the people outside in the free population group was determined for the time in question from Tables C. 5 and C. 11 of Ref. 3.

Thus, by combining all of the above data the following three equations were derived for the three stated times of day:

<u>11:00 a. m.</u>

0.4 (mining)* + 0.8 (construction) + 0.016 (manufacturing) + 0.28 (railroad)

+ 0.6 (other transportation + communications) + 0.16 (other work)

+ 0.095 (free + 0.2 (employed) + 0.07 (school)) = outside population

* "Mining" refers to the population engaged in mining at the stated time.

5:30 p. m.

0.15 (mining) + 0.3 (construction) + 0.006 (manufacturing) + 0.105 (railroad) + 0.225 (other transportation + communications) + 0.06 (other work) + 0.189 (free + 0.7 (employed) + school) = outside population

2:30 a. m.

0.015 (mining) + 0.03 (construction) + 0.0006 (manufacturing) + 0.0105 (railroad) + 0.0225 (other transportation + communications) + 0.006 (other work) + 0.00545 (free + 0.97 (employed) + school) = outside population

At each of the above times the total population equals the sum of the free population, the employed population, and the school population. Thus, for each time of day the percent of the population outside structures equals the outside population divided by the total population. The employed, school, and total populations were obtained from the census data for each specific city.

Utilizing the above three equations, a sample was taken of twenty-two cities geographically scattered throughout the continental United States, excluding Alaska. The cities, ranging in population from that of New York, N. Y., to Laredo, Texas, are listed in Table 45. The results of this survey are presented in Table 46.

TABLE 45

CITIES ANALYZED FOR "OUTSIDE POPULATION" STUDY

1. Abilene, Texas
2. Atlantic City, New Jersey
3. Boston, Massachusetts
4. Columbia, South Carolina
5. Denver, Colorado
6. Erie, Pennsylvania
7. Lansing, Michigan
8. Laredo, Texas
9. Little Rock, Arkansas
10. Los Angeles and Long Beach, California
11. Louisville, Kentucky
12. Miami, Florida
13. Minneapolis and St. Paul, Minnesota
14. Mobile, Alabama
15. New York, New York
16. New York (outside city proper), New York
17. Salt Lake City, Utah
18. San Francisco, California
19. St. Louis, Missouri
20. Tucson, Arizona
21. Washington, D. C.
22. Wichita, Kansas

TABLE 46

PERCENTAGE OF POPULATION OUTSIDE STRUCTURES

Time of Day	Percent Outside	Percentage Standard Deviation
11:00 a.m.	9.00	0.755
5:30 p.m.	18.50	0.258
2:30 a.m.	0.705	0.024

Noting the small percentage standard deviations given in Table 46, it is evident that each of the three population percentages outside will adequately represent the fraction of the total population that is outside at the stated time (insofar as this equation and these cities are concerned). As these cities range widely in population and geographical location, it appears that the percentages presented in Table 46 will be adequate for virtually all of the cities in the continental United States, excluding Alaska.

B. APPLICATION TO CASUALTY CURVES

From Table 46 it is seen that about 9.0 percent of the urban population are outside at 11:00 a.m., whereas 18.5 percent are outside at 5:30 p.m., during rush hour. As an average to use during the daytime, a value of 13 percent* was chosen to represent the percentage of the population outside. The construction percentages in Table 44 were then reduced proportionately in order to add to 87 percent instead of 100 percent. (Note that the assumption is implied that people are distributed by structural type according to the above-ground floor area.)

Table 47 thus presents the list of typical areas and their various construction percentages which were used to draw the casualty curves. The population percentage outside was divided up into those who were outside and shielded (OS) and those who were outside and unshielded (OU). This division varied according to the typical area or land use.

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* The casualty curves are not very sensitive to the magnitude of this value.

TABLE 47

TYPICAL URBAN AREAS FOR CASUALTY CURVES

(Some Population Outside)

Category	Percent Construction by Type							
	WF	BR	ARC	JRC	HSF	LSF	OS	OU
1. Downtown in Large Cities and High Apartment Bldgs.	3	30	52	1	1	0	6	7
2. Downtown in Medium Cities	12	35	37	1	2	0	5	8
3. Downtown in Small Cities and Suburban Shopping	12	48	22	0	4	1	5	8
4. Light Manufacturing, Heavy Manufacturing in Medium Cities, and Warehouses	11	38	31	1	4	2	5	8
5. Heavy Manufacturing in Large Cities	18	23	36	2	6	2	5	8
6. Heavy Manufacturing in Small Cities	26	55	2	0	4	0	5	8
7. Low Apartment Bldgs. and Large Residences	31	46	9	0	1	0	4	9
8. Small Residences in Large Cities	47	38	2	0	0	0	4	9
9. Small Residences in Medium Cities	58	27	2	0	0	0	4	9
10. Small Residences in Small Cities	70	16	1	0	0	0	4	9

CHAPTER VIII

CASUALTY CURVES

A. TOTAL INJURY CURVES BY CONSTRUCTION TYPE

A complete set of mortality and injury curves was developed in a previous Dikewood Corporation report, DC-FR-1028 (Ref. 4). However, the injury curves were separated as to blast, thermal, and nuclear in that report. Since numerous people were injured in more than one way, the sum of these injury curves often added to more than 100 percent and had no physical meaning. Of course, the purpose of the previous presentation was to provide data on the medical load, i.e., the number of cases of each type of injury. Total injury curves by construction type have now been prepared in this report to complete the picture.

It was also apparent that the blast injury curves by construction type in DC-FR-1028 predicted injuries at too great a range. This effect arose because for lack of anything better the blast mortality scaling factors were also applied to the injury curves. These scaling factors were greater than ordinary cube-root scaling ($W^{0.33}$) due to the effects of dynamic pressure on structural damage in the high-overpressure region. It is now felt that the tails of the blast injury curves should conform to cube-root scaling since the injuries are primarily due to overpressure alone at these longer ranges. In order to provide smooth curves, the scaling factors were gradually increased

with decreasing range from the tails until they merged with the blast mortality scaling factors. The point of merging is physically associated with the region just prior to the peak of the injury curves (and thus with the tails of the mortality curves). However, in no case was the maximum percentage of injuries for the original blast injury curves appreciably altered. The previous mortality curves were unchanged and are correct.

Similarly, it was felt that the thermal injury curves fo. tı · outside-unshielded category predicted injuries at too great a range. Thus, these curves were revised slightly, and the revision is reflected in the new total injury curves for the outside-unshielded category, which are due predominantly to the thermal data.

The total injury curves by construction type were then drawn with the primary emphasis on the blast injury curves but with the thermal and nuclear injury curves making contributions when applicable. For the yields of interest the nuclear injury curves did not make any significant contribution to the total injuries, with the exception of the Japanese reinforced-concrete buildings; at close ranges the nuclear injury curves had some effect on the total injuries for these buildings. With increasing yield, thermal radiation becomes increasingly more important than blast at the longer ranges. Thus, the main result of the thermal injury curves was to extend the tails of the total injury curves--all in a very similar manner. The total injury curves by construction type are presented in Figs. 8 through 15 for

surface bursts and yields of 0.4, 1, 4, 10, 25, and 50 Mt. Similar total injury curves are presented in Figs. 16 through 23 for Hiroshima scaled heights of burst* and the same yields. (All casualty curves are presented at the end of this chapter.)

It should again be noted, as it was in DC-FR-1028, that these curves apply only for fairly low structures less than five to ten stories in height. Of course, the reason for this restriction is that the buildings in Hiroshima (the data source) were all low in height.

B. TOTAL MORTALITY AND INJURY CURVES FOR TYPICAL URBAN AREAS (DAYTIME--SOME POPULATION OUTSIDE)

Table 47 gives the construction percentages for the various types of construction or shielding for the ten typical urban areas. The various construction types which were used were based on DC-FR-1028 and are as follows: Japanese reinforced concrete (JRC), American reinforced concrete (ARC), heavy steel frame (HSF), light steel frame (LSF), brick (BR), and wood frame (WF). In addition, there are the categories for people who were outside and shielded (OS) and those who were outside and unshielded (OU).

Utilizing the total mortality curves by construction type from DC-FR-1028, the total injury curves by construction type which were just

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*The Hiroshima scaled height of burst is 846 feet.

developed, and the various construction percentages in Table 47,* total mortality and total injury curves were constructed for an unwarned population (daytime) for each of the ten typical urban areas. The curves were constructed point by point by multiplying the construction fraction from Table 47 by the mortality or injury fraction for the desired range and yield on the mortality or injury curve of corresponding construction. The results of the above products were then summed over all eight shielding or construction categories and then plotted as a single point for the same range and yield for the particular mortality or injury curve (and typical area) under consideration. (Note that this procedure again implies that people are distributed by structural type according to the above-ground floor area.)

During the analysis of these curves, categories two and five of Table 47 were found to provide similar results, primarily because of the large size and nearly equal magnitude of American reinforced-concrete construction in the two categories. Thus, these two categories were combined in presenting the resulting curves.

The total mortality curves for surface bursts are presented in Figs. 24 through 32 for yields of 0.4, 1, 4, 10, 25, and 50 Mt. The total injury curves for surface bursts are given in Figs. 33 through 41 for the same yields. (The categories are defined in Table 47.)

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* Note that these data are based on 13 percent of the population being outside. (Normalized curves are presented in Section D for the case of "no population outside.")

The total mortality curves for the Hiroshima scaled heights of burst* are presented in Figs. 42 through 50 for yields of 0.4, 1, 4, 10, 25, and 50 Mt. The total injury curves for the Hiroshima scaled heights of burst* are given in Figs. 51 through 59 for the same yields. (The categories are defined as before in Table 47.) As in the basic data, the above curves apply only for fairly low structures less than five to ten stories in height.

It should again be noted that the above curves are all based on an unwarned-daytime population with 13-percent of the population outside. It was felt that this configuration could be more accurately represented since an unwarned population data base (Hiroshima) was the primary source of information. Other population distributions are presented in Section D.

For ease in comparing results for a given yield and burst height, Figs. 60 and 61 were prepared showing all the categories for mortality and injury, respectively, for a 10-Mt surface burst. From this presentation it can be seen that the heavier construction provides a lower mortality rate and a higher injury rate. Of course, the increased injury rate is due to the heavy debris from such buildings.

C. TOTAL CASUALTY CURVES FOR TYPICAL URBAN AREAS (DAYTIME--SOME POPULATION OUTSIDE)

After completing the total mortality and injury curves for the typical urban areas, the next step was to sum them and obtain total casualty curves.

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* The Hiroshima scaled height of burst is 846 feet.

The resulting curves are not presented here, but some of the findings may be of interest. It became evident that the casualty curves varied significantly only for three different groups of typical urban areas. These groupings were divided into heavy construction, consisting of categories 1 through 5 from Table 47, medium construction, consisting of categories 6 through 8, and light construction, consisting of categories 9 and 10.

None of the casualty curves were radically different. Of course, the reason is that the heavy buildings provided fewer fatalities but more injuries, whereas the lighter buildings provided more fatalities but nearly the same total fraction of casualties as the heavier buildings.

D. ATTACK CONDITIONS

Of course, all of the curves previously described are for an unwarned daytime population. However, certain approximations may be made with these curves to arrive at nighttime and warned configurations.

1. Unwarned-Nighttime Mortality and Injury Curves for Typical Urban Areas (No Population Outside)

To derive this new set of curves from the previous unwarned-daytime curves, two changes were made as follows: (1) the people outside were proportionally redistributed to inside locations and (2) the tails of the mortality and injury curves resulting from this calculation were then lowered further to eliminate the thermal contribution to casualties within shielding structures (through windows). However, the leading edges and peaks of the new

injury curves had to be raised to offset the lowering of the tails of the mortality curves. Thus, some of the mortalities were replaced by injuries. Normalized versions of this set of curves are presented in Fig. 62 for the mortality curves and in Fig. 63 for the injury curves.

For the mortality curves it was found that a single normalized curve would cover adequately all of the typical areas, yields, and burst heights. However, for the injury curves it was found that three normalized curves were required to cover adequately the various typical areas. (Yield and burst height had only minor effects on the normalized injury curves.) Group 1 represents typical-area categories 1 through 5 of Table 47; group 2 represents categories 6 through 8; and group 3 represents categories 9 and 10.

To utilize these normalized curves, one merely examines the appropriate unwarned-daytime curve from Figs. 24 through 59 at some fixed range to find the percent mortality or injury, as the case may be. Using this value as the abscissa on the appropriate normalized curve, the corresponding percent mortality or injury at the same fixed range for an <u>unwarned-nighttime</u> condition is read from the ordinate of the normalized curve. This procedure is repeated for all desired ranges. One should note that the mortality and injury curves thus obtained for an unwarned-nighttime condition are somewhat less reliable than those curves drawn for the unwarned-daytime configuration.

FIG. 62
NORMALIZED CURVE FOR NIGHTTIME VS DAYTIME MORTALITY

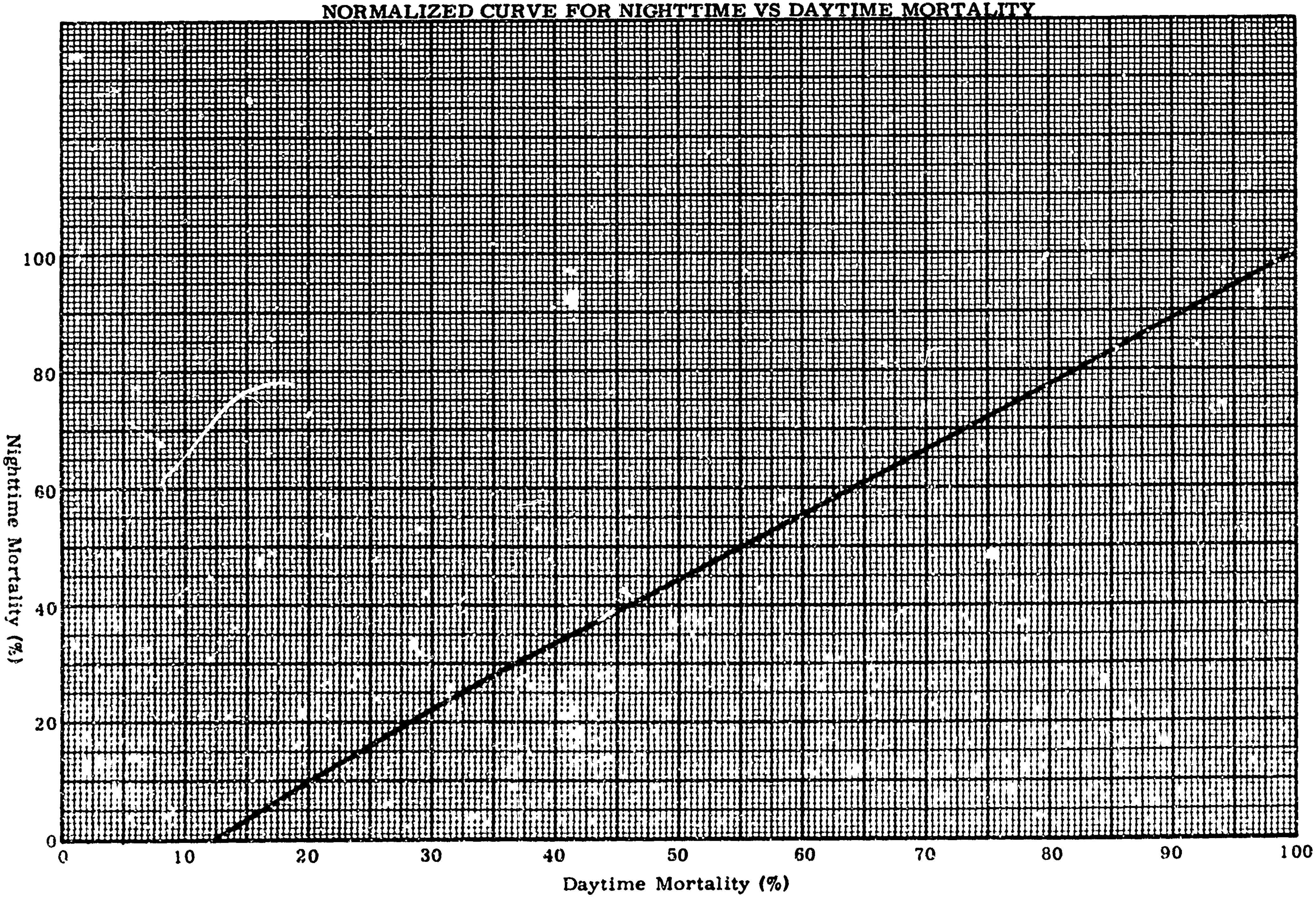
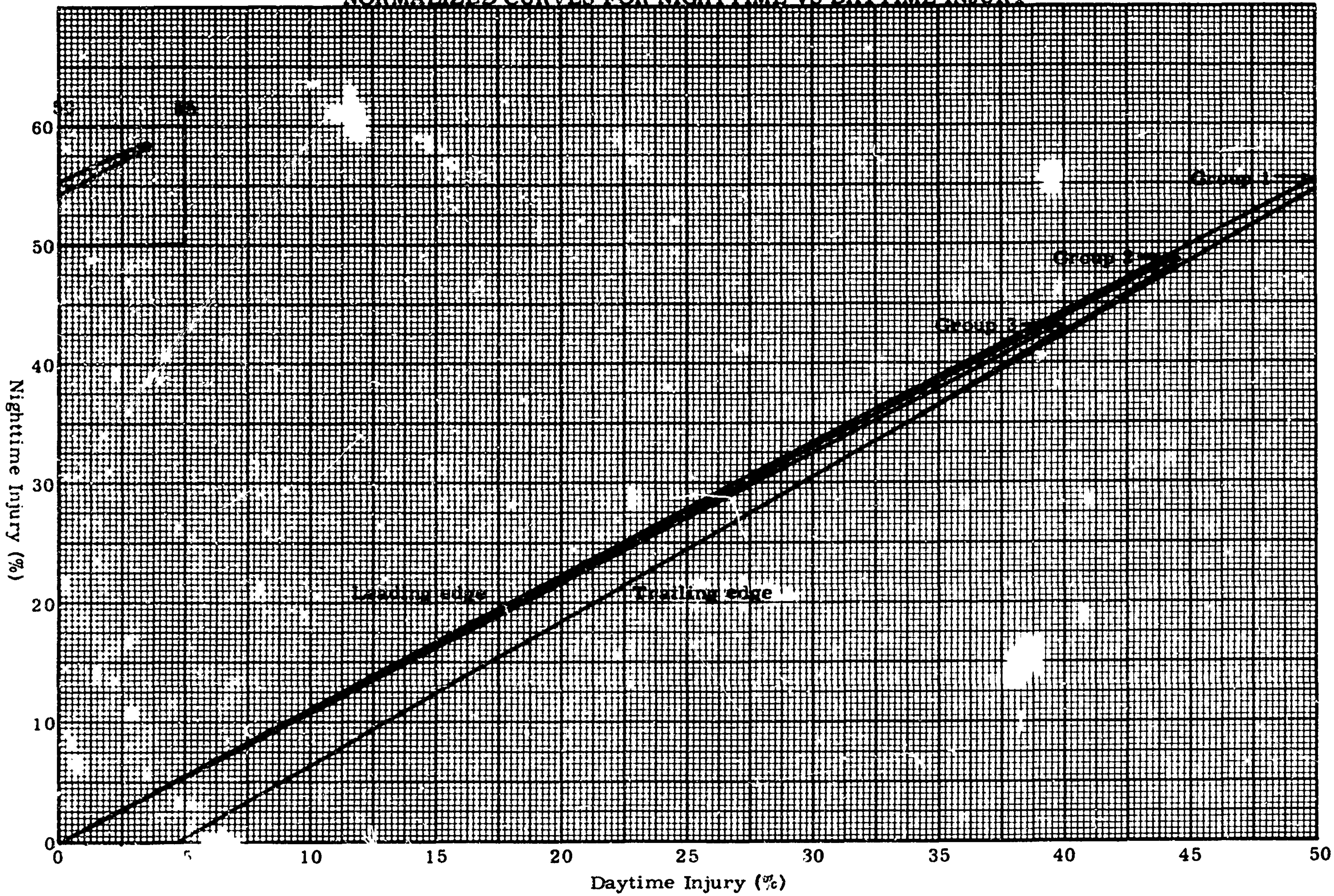


FIG. 63
NORMALIZED CURVES FOR NIGHTTIME VS DAYTIME INJURY



To illustrate the above procedure, consider a point on the 10-Mt curve of Fig. 33 at a range of 20 kft. The percent injury for an unwarned-daytime configuration is read as 32.5 percent. Since this curve is for category 1, one should read the leading edge of the normalized group-1 curve in Fig. 63 where the abscissa for daytime injury also reads 32.5 percent. The ordinate, giving the nighttime injury percentage with all of the population inside, can then be read as 36.2 percent.

2. Warned Mortality and Injury Curves for Typical Urban Areas (No Population Outside)

These curves, which apply during either day or night, were obtained by lowering the tails of the unwarned-nighttime mortality and injury curves to reflect the better shielding posture of the warned personnel. (One should note that the people are still distributed throughout the building.) Again, the leading edges and peaks of the new injury curves rise to offset the lowering of the tails of the mortality curves. Thus, some of the mortalities were replaced by injuries. Normalized versions of this set of curves are presented in Fig. 64 for the mortality curves and in F. 65 for the injury curves.

Again, it was found that a single normalized curve would cover adequately all of the typical areas, yields, and burst heights for the mortality curves. However, three normalized curves were required as before to

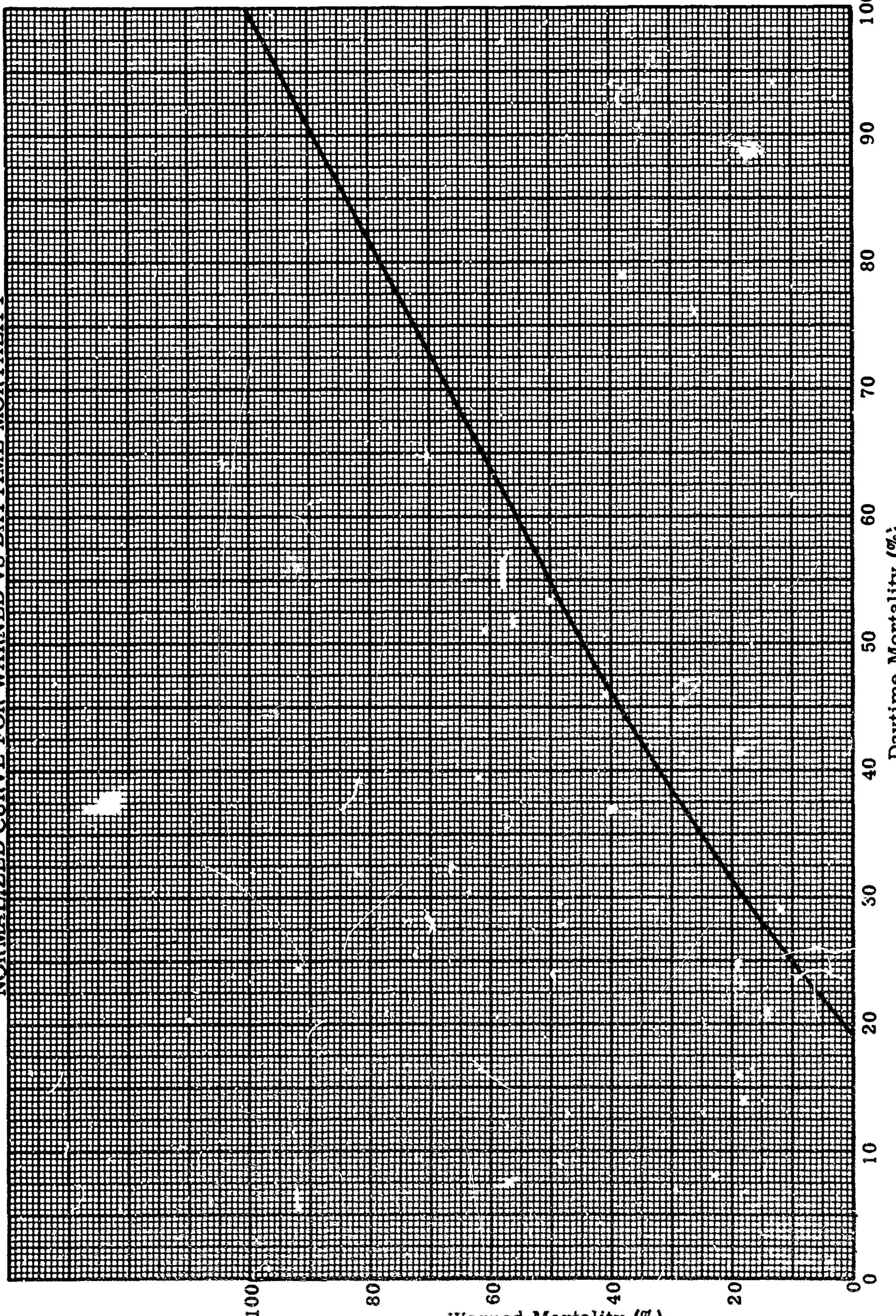
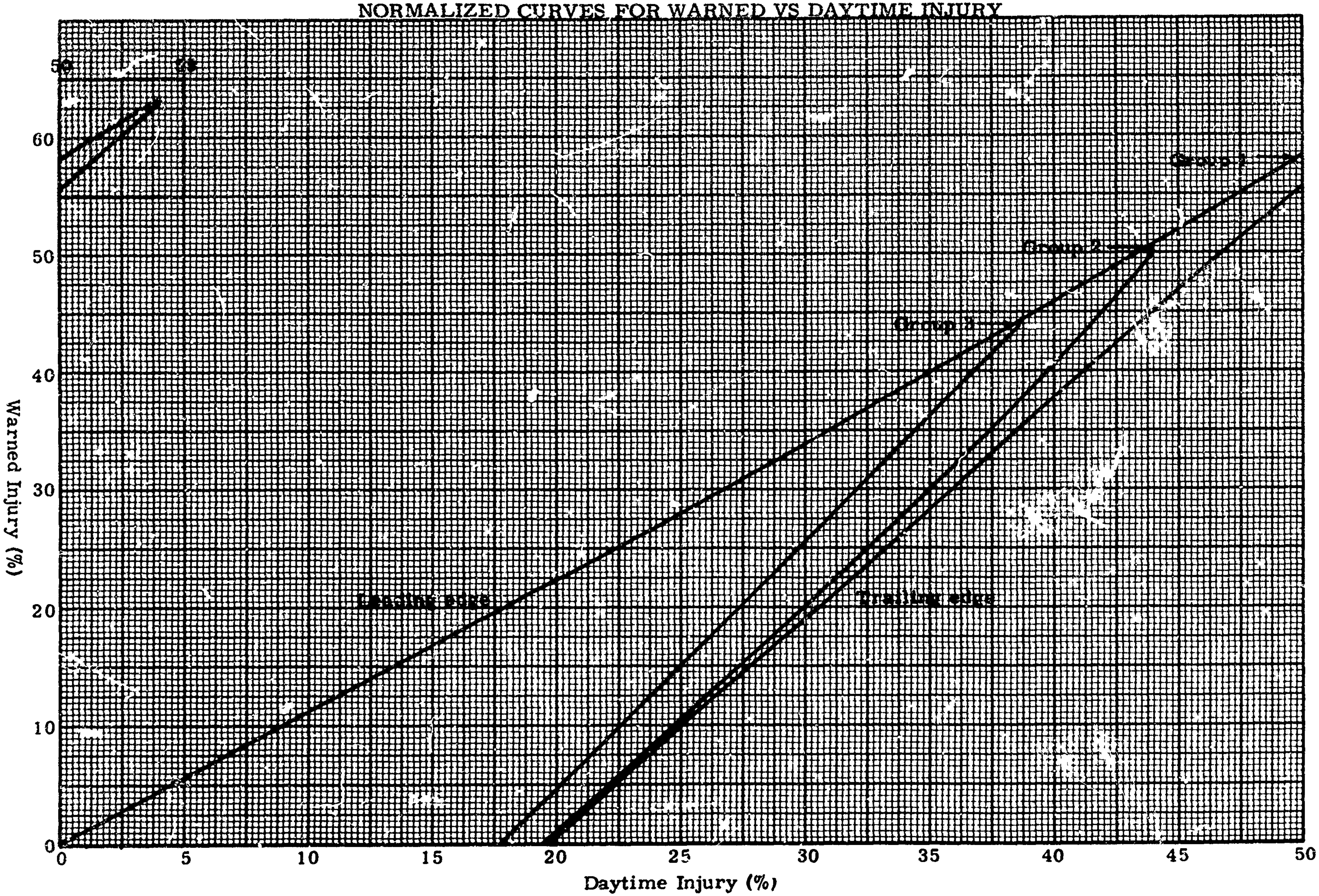


FIG. 64
NORMALIZED CURVE FOR WARNED VS DAYTIME MORTALITY

FIG. 65
NORMALIZED CURVES FOR WARNED VS DAYTIME INJURY



cover adequately the various typical areas for the injury curves. (Groups 1, 2, and 3 have the same meaning as that defined in the preceding section.)

The utilization of these normalized curves is the same as that described in the preceding section, except that now the percent mortality or injury as read from the ordinate of the appropriate normalized curve applies to a warned condition. These warned curves are only estimates and are the least reliable of the mortality and injury curves presented in this report.

E. NATIONAL CASUALTY ASSESSMENT

In order to make a national casualty assessment utilizing the set of mortality and injury curves classified by typical urban area, one needs land-use maps for the various cities of interest across the country. These maps allow one to determine the physical locations within the cities which may be associated with a given "typical" urban area as defined in this report. This association then determines the set of mortality and injury curves to be applied.

A note of caution should be injected into the discussion at this point. The mortality and injury curves classified by typical urban areas were developed primarily for national casualty assessment. When they are used for one or a few cities, the results may not average out as they would on a national basis, thus, the casualties may be slightly overestimated or underestimated, as the case may be.

FIG. 8
TOTAL INJURY CURVES FOR JAPANESE REINFORCED-CONCRETE BUILDINGS FROM SURFACE BURSTS

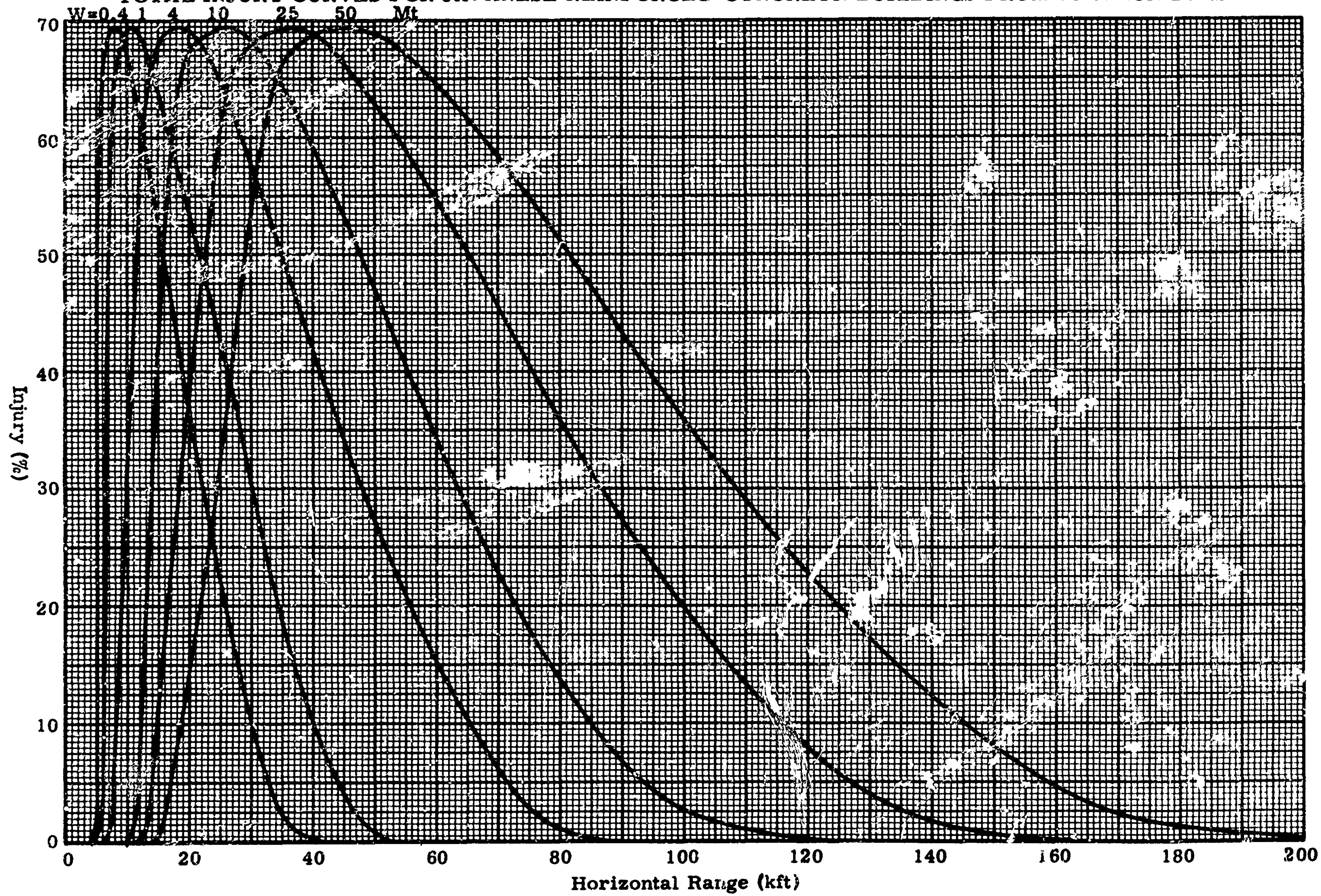


FIG. 9
TOTAL INJURY CURVES FOR AMERICAN REINFORCED-CONCRETE AND MULTISTORY STEEL-FRAME BUILDINGS FROM SURFACE BURSTS

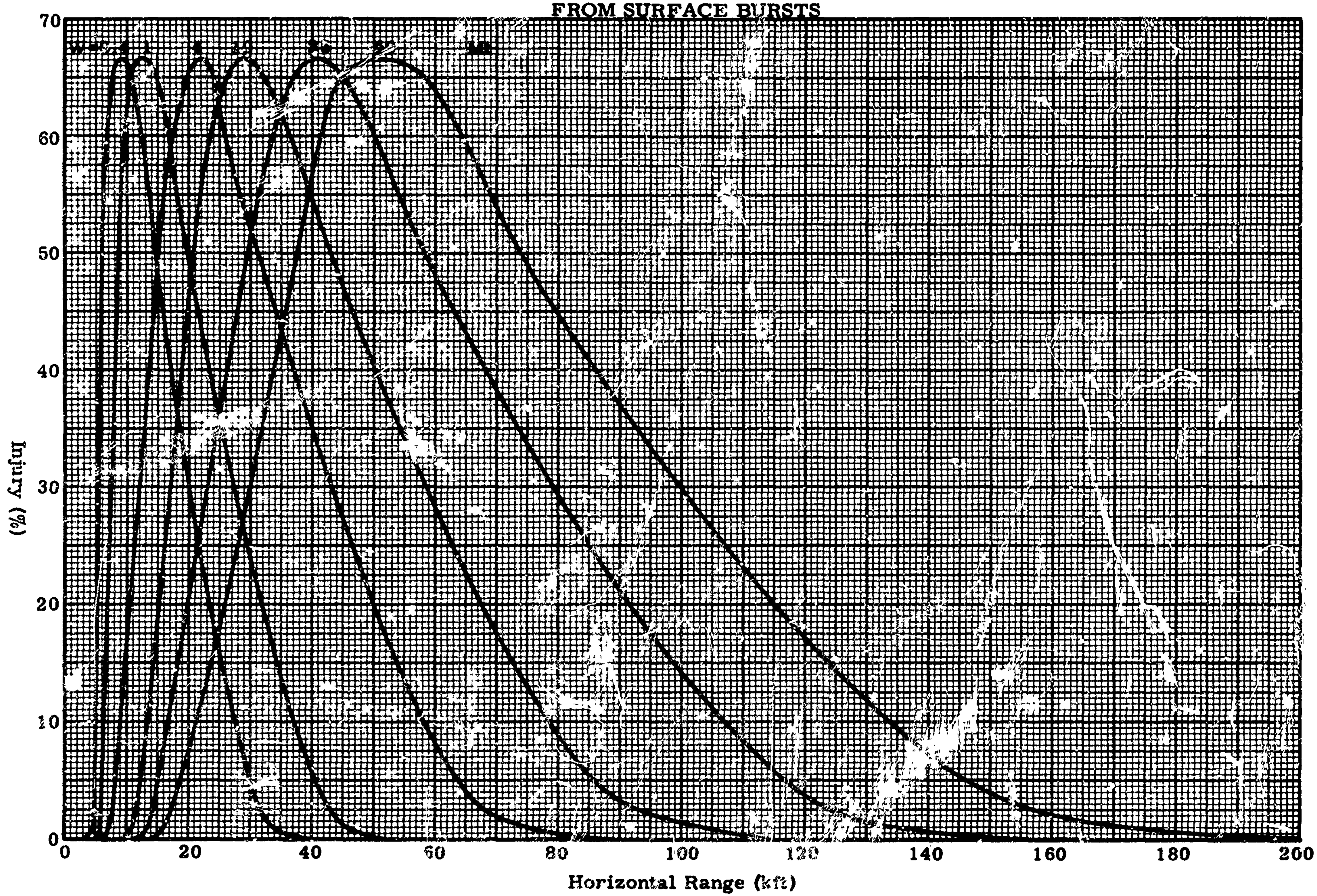


FIG. 10

TOTAL INJURY CURVES FOR HEAVY STEEL-FRAME BUILDINGS FROM SURFACE BURSTS

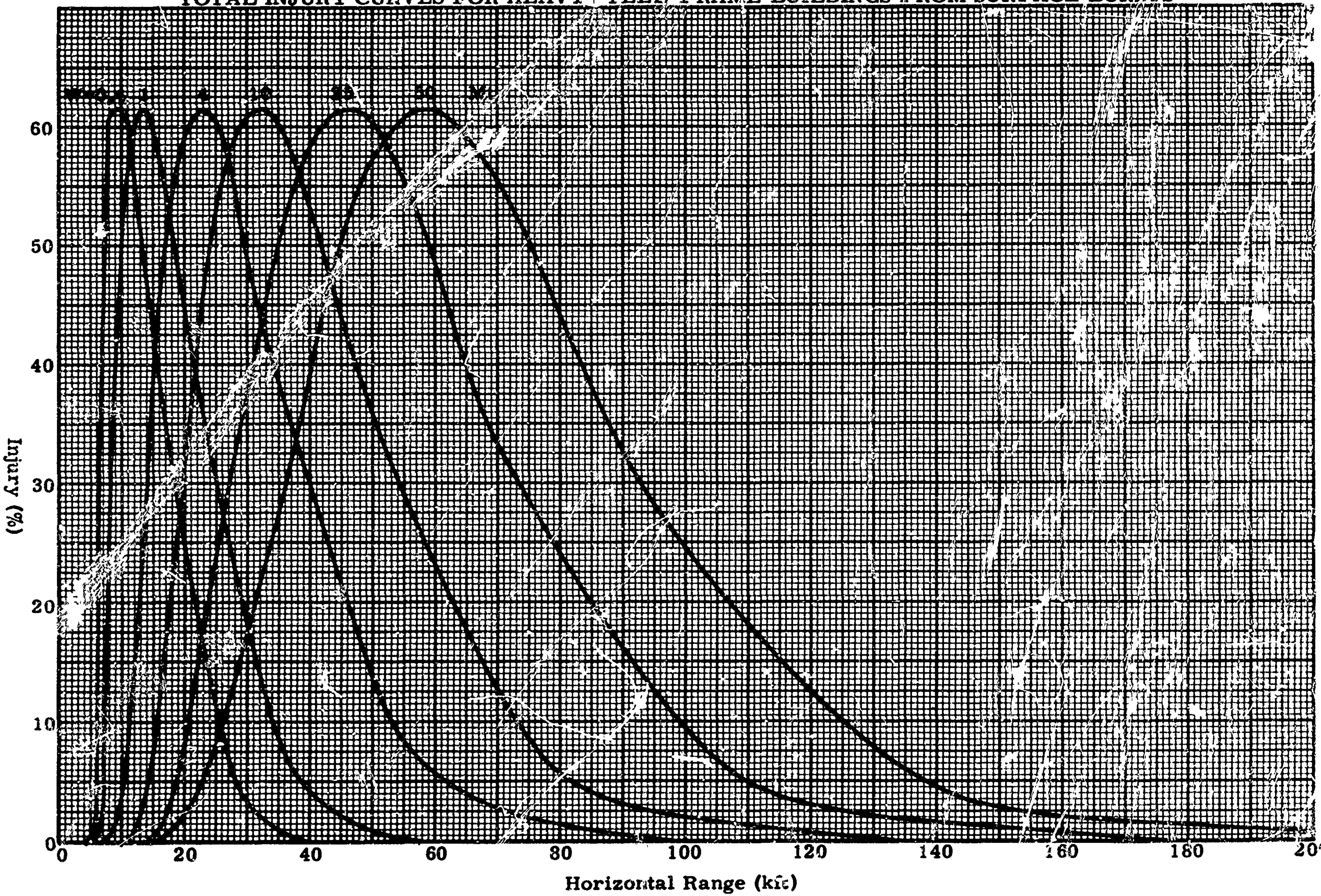


FIG. 11

TOTAL INJURY CURVES FOR LIGHT STEEL-FRAME BUILDINGS FROM SURFACE BURSTS

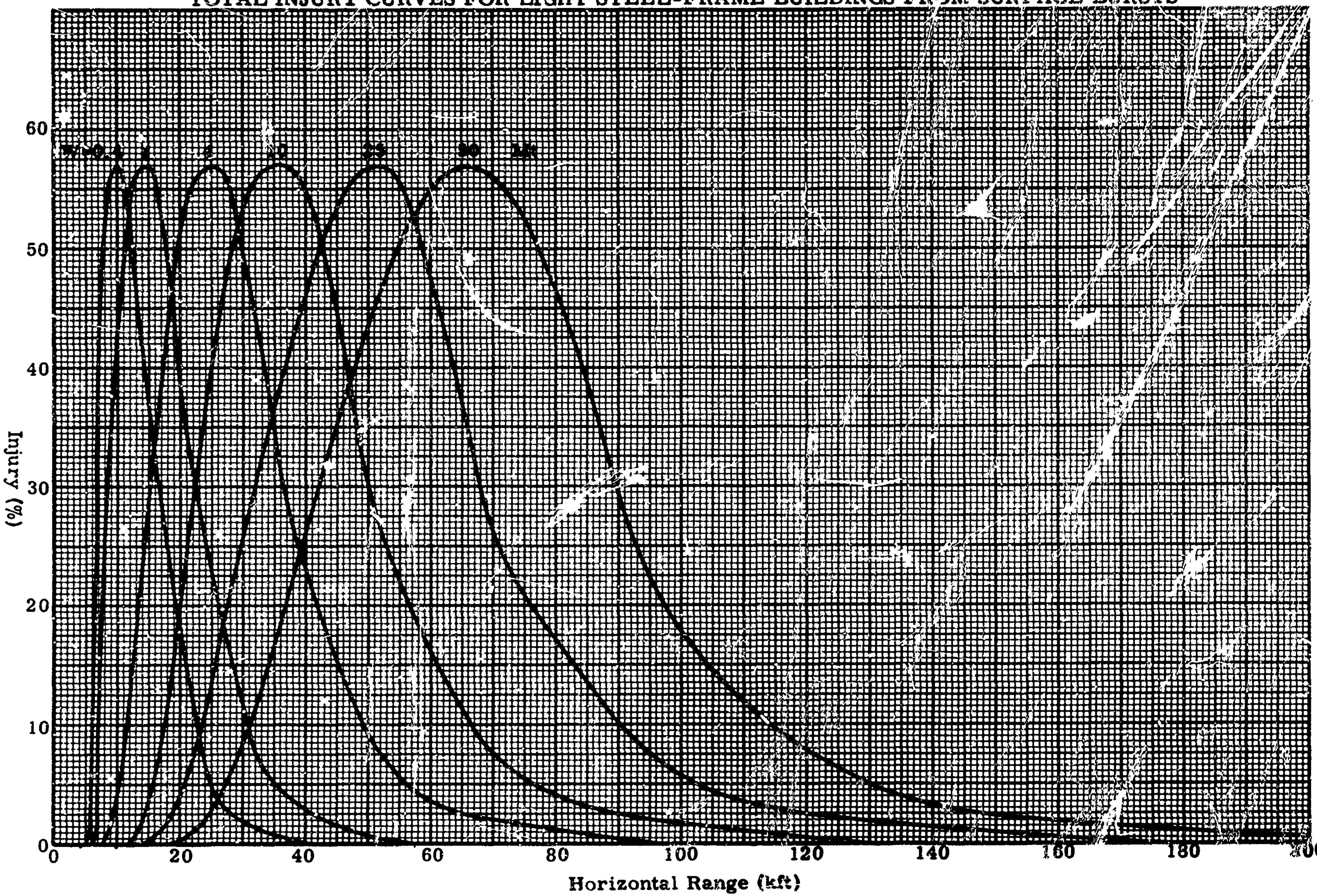


FIG. 12

TOTAL INJURY CURVES FOR WALL-BEARING BRICK BUILDINGS FROM SURFACE BURSTS

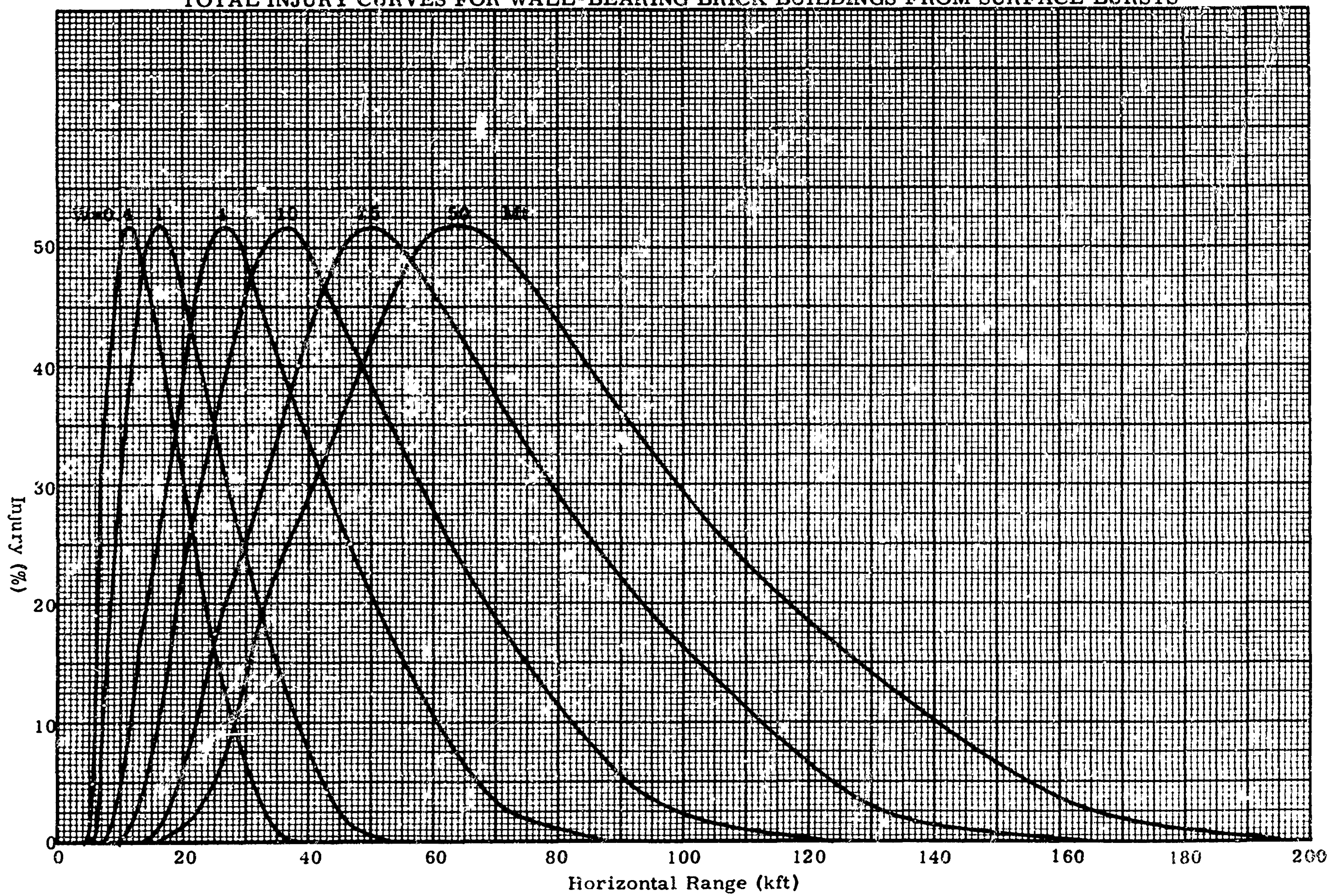
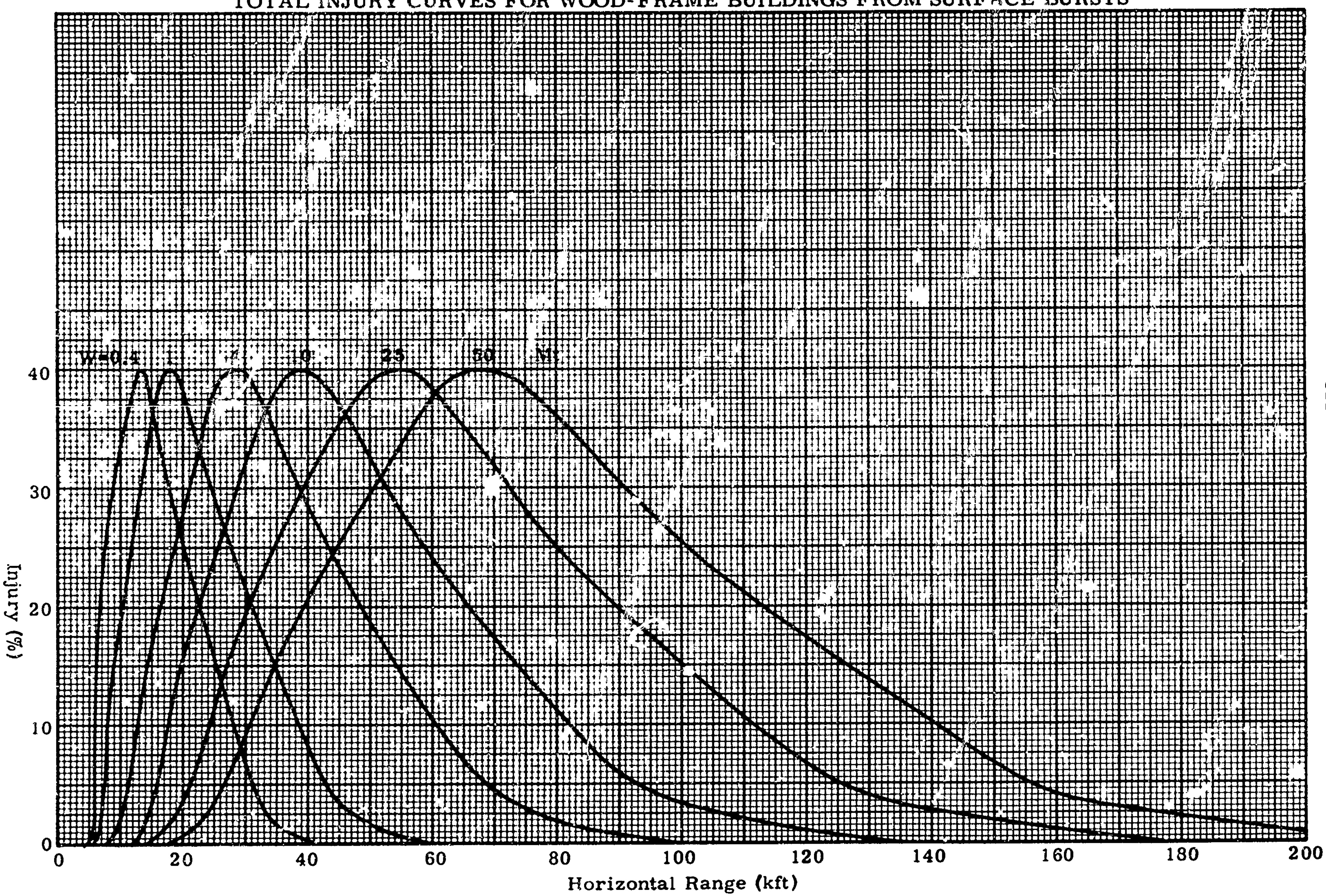


FIG. 13

TOTAL INJURY CURVES FOR WOOD-FRAME BUILDINGS FROM SURFACE BURSTS



Horizontal Range (kft)

FIG. 14

TOTAL INJURY CURVES FOR OUTSIDE-SHIELDED CATEGORY FROM SURFACE BURSTS

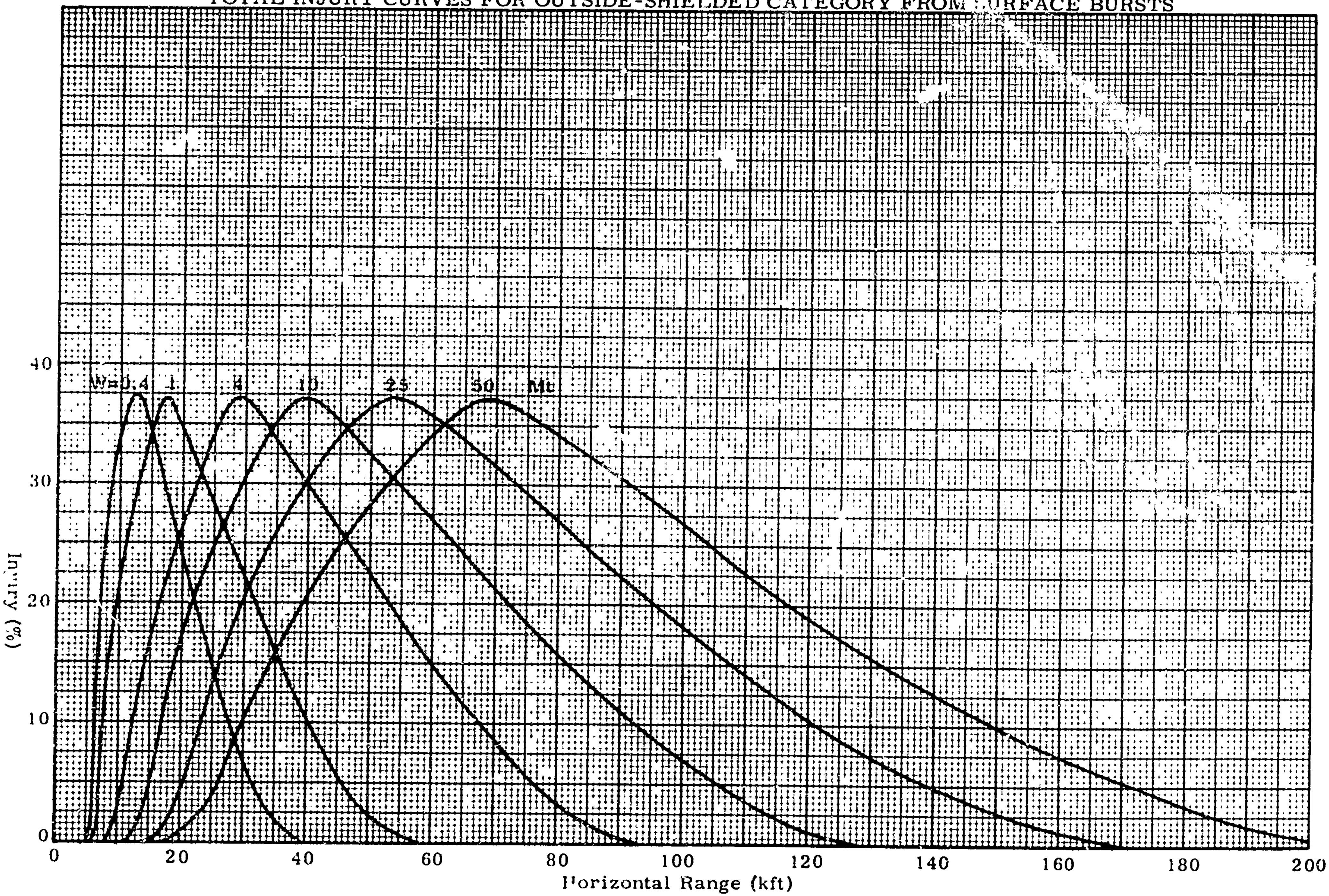


FIG. 15

TOTAL INJURY CURVES FOR OUTSIDE-UNSHIELDED CATEGORY FROM SURFACE BURSTS

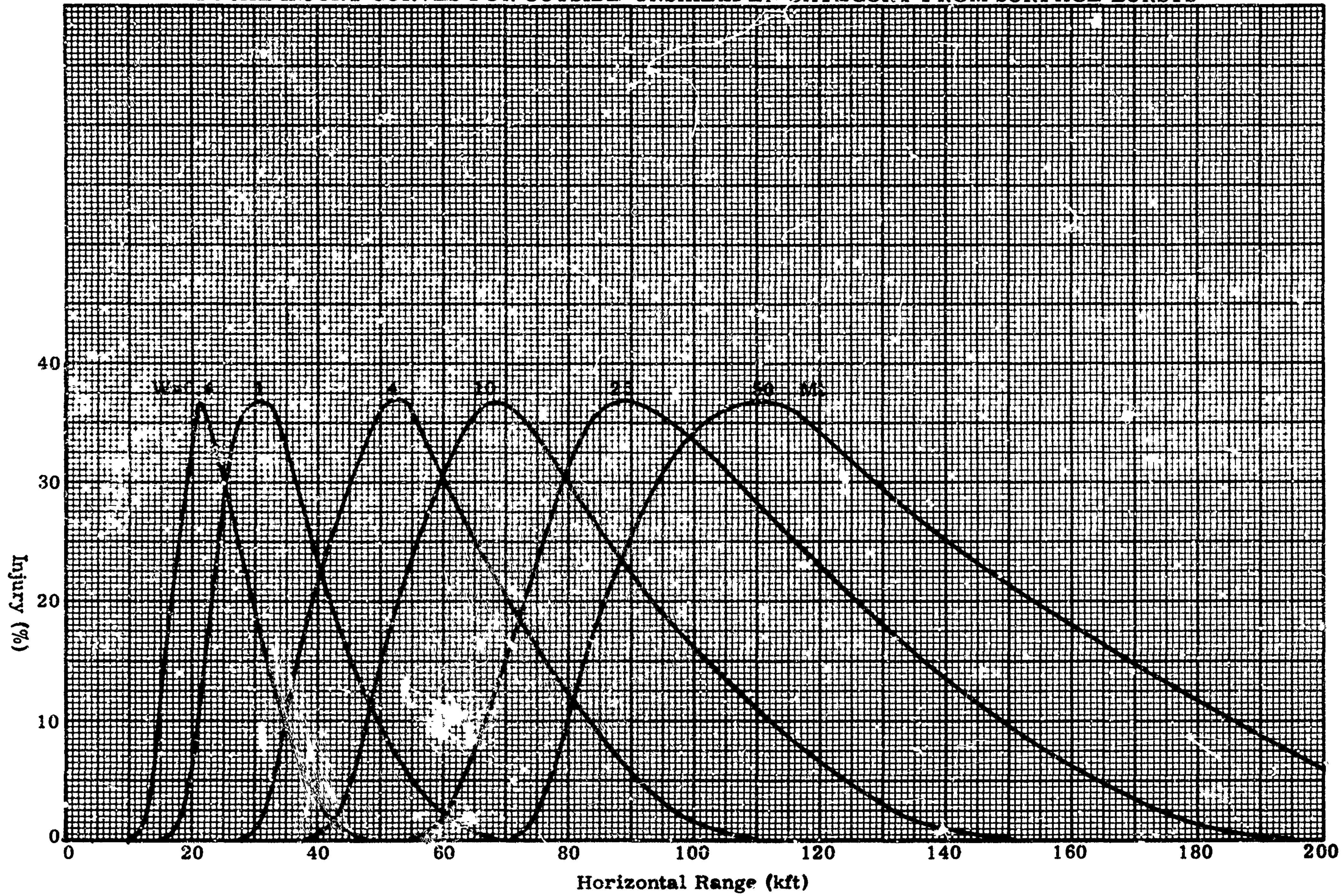


FIG. 16

FIG. 16
TOTAL INJURY CURVES FOR JAPANESE REINFORCED-CONCRETE BUILDINGS
FROM HIROSHIMA SCALED BURST HEIGHTS

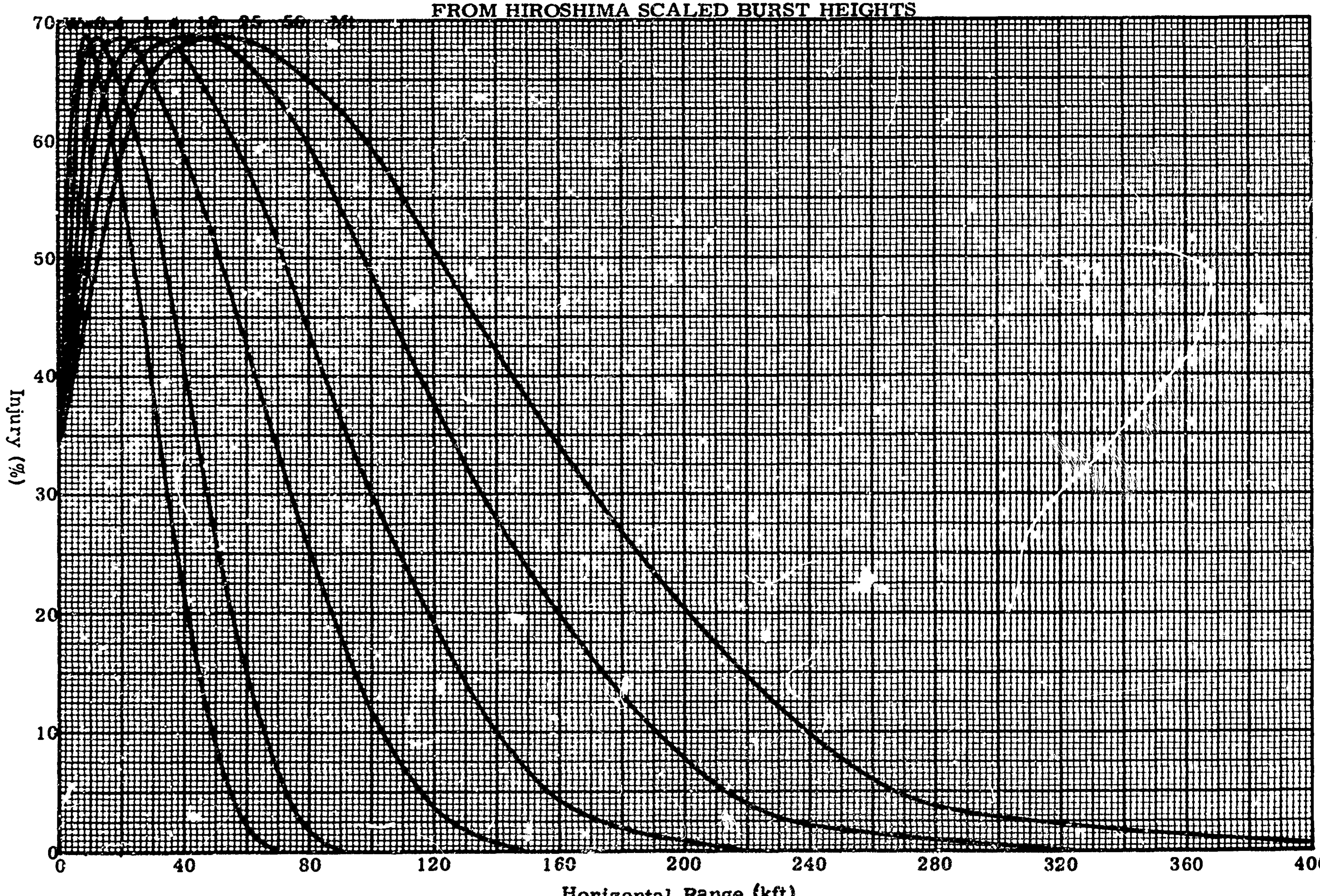


FIG. 17
TOTAL INJURY CURVES FOR AMERICAN REINFORCED-CONCRETE AND MULTISTORY STEEL-FRAME BUILDINGS FROM HIROSHIMA SCALED BURST HEIGHTS

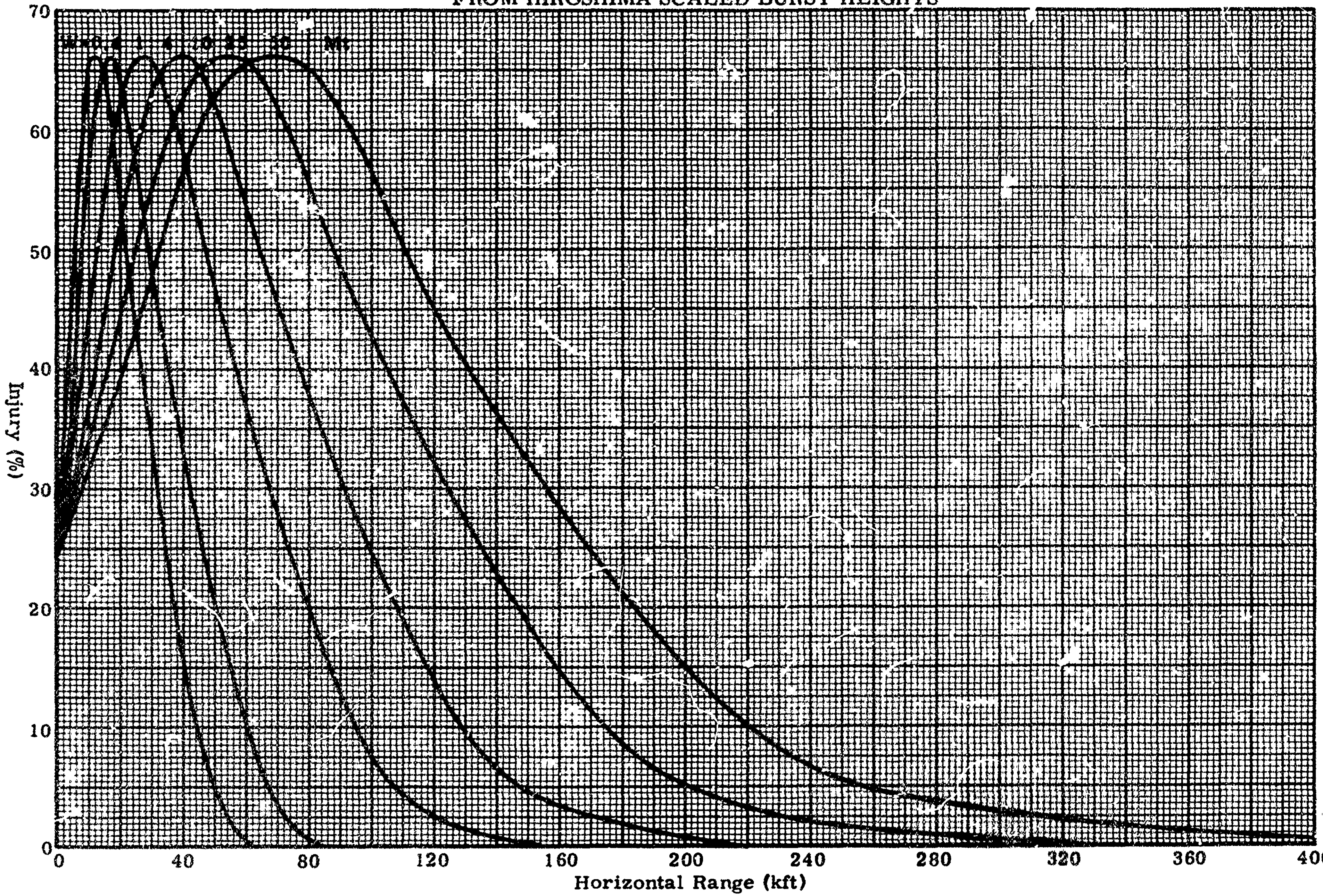


FIG. 18

TOTAL INJURY CURVES FOR HEAVY STEEL-FRAME BUILDINGS FROM HIROSHIMA SCALED BURST HEIGHTS

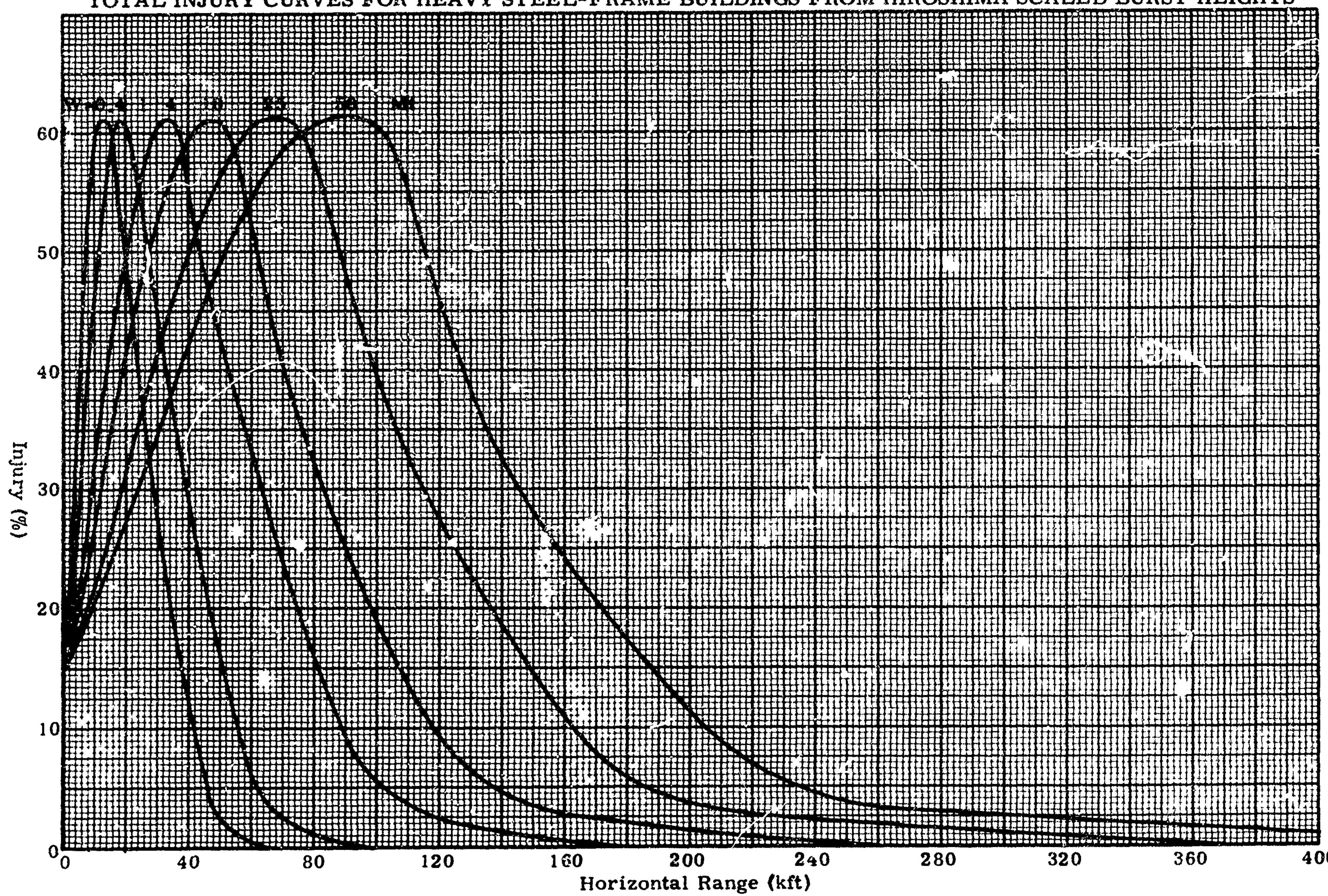


FIG. 19

TOTAL INJURY CURVES FOR LIGHT STEEL-FRAME BUILDINGS FROM HIROSHIMA SCALED BURST HEIGHTS

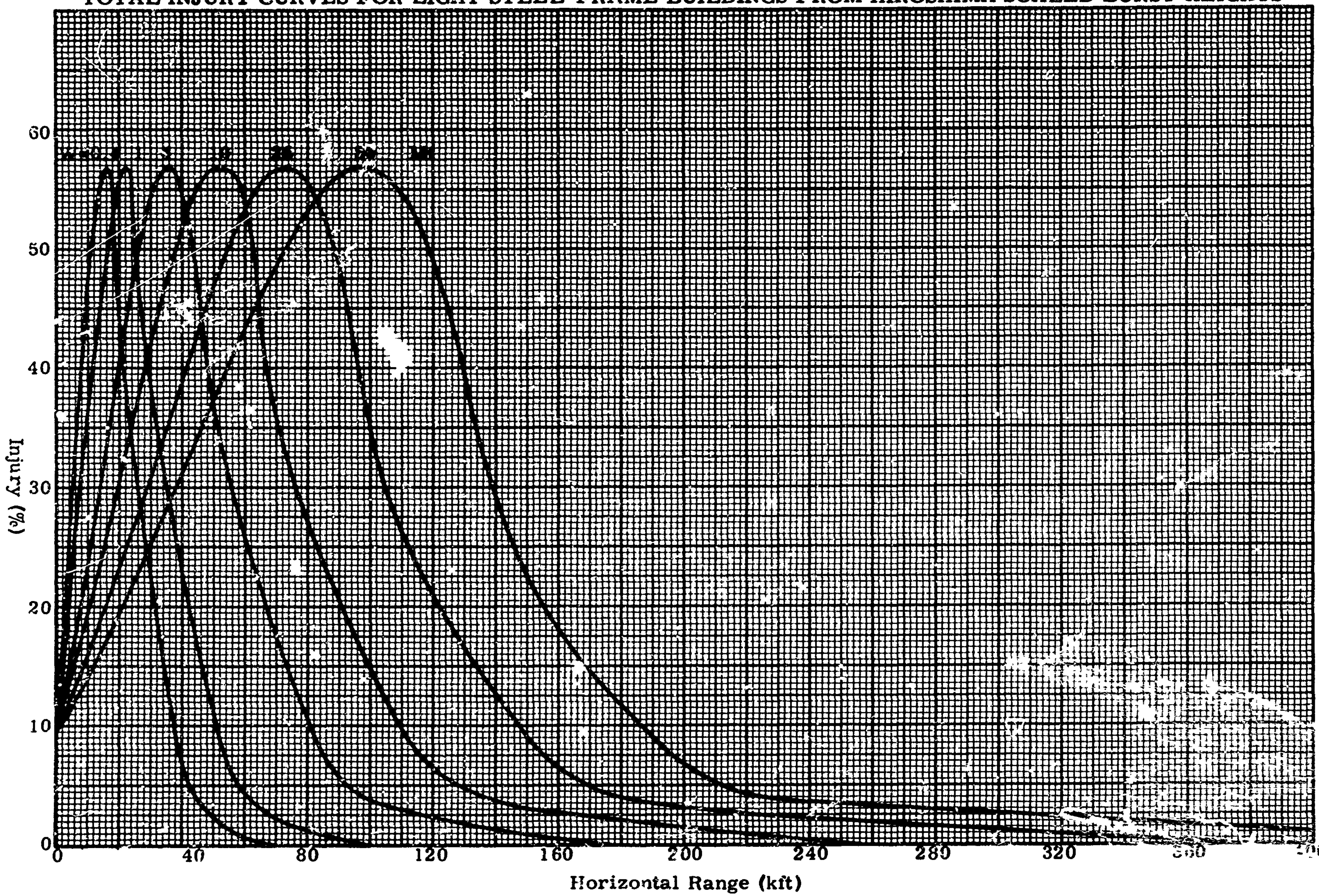


FIG. 20

TOTAL INJURY CURVES FOR WALL-BEARING BRICK BUILDINGS FROM HIROSHIMA SCALED BURST HEIGHTS

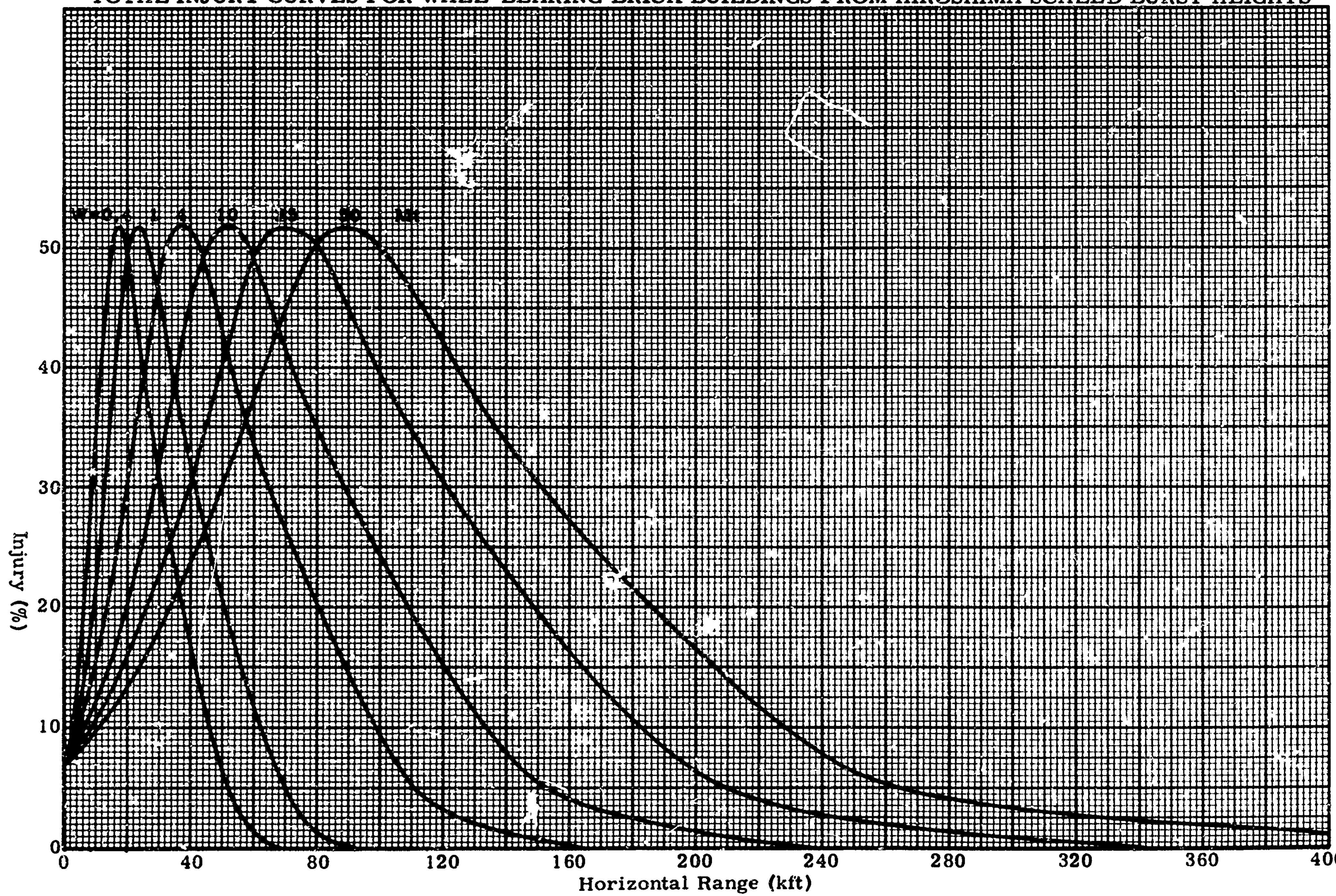


FIG. 21

TOTAL INJURY CURVES FOR WOOD-FRAME BUILDINGS FROM HIROSHIMA SCALED BURST HEIGHTS

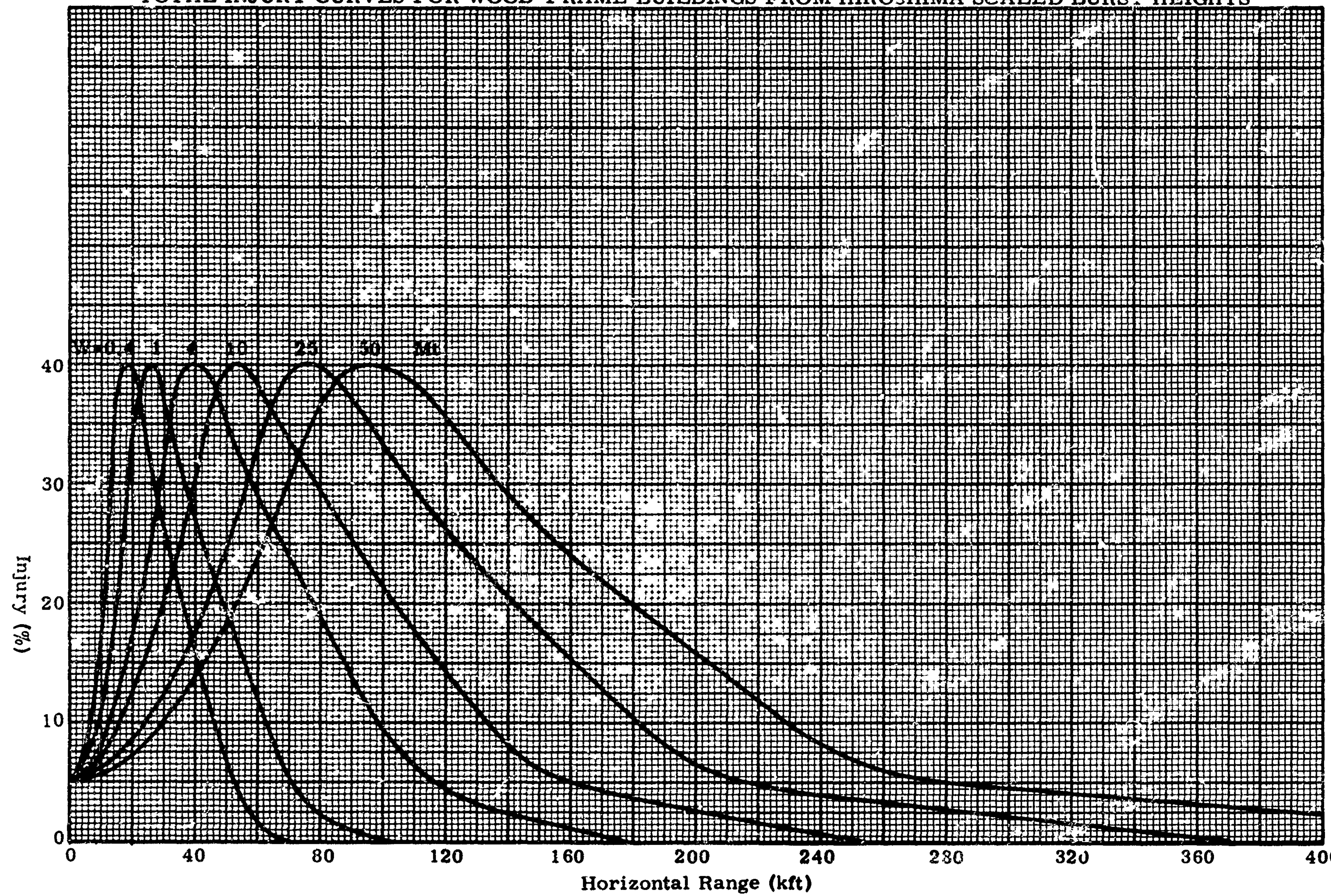


FIG. 22

TOTAL INJURY CURVES FOR OUTSIDE-SHIELDED CATEGORY FROM HIROSHIMA SCALED BURST HEIGHTS

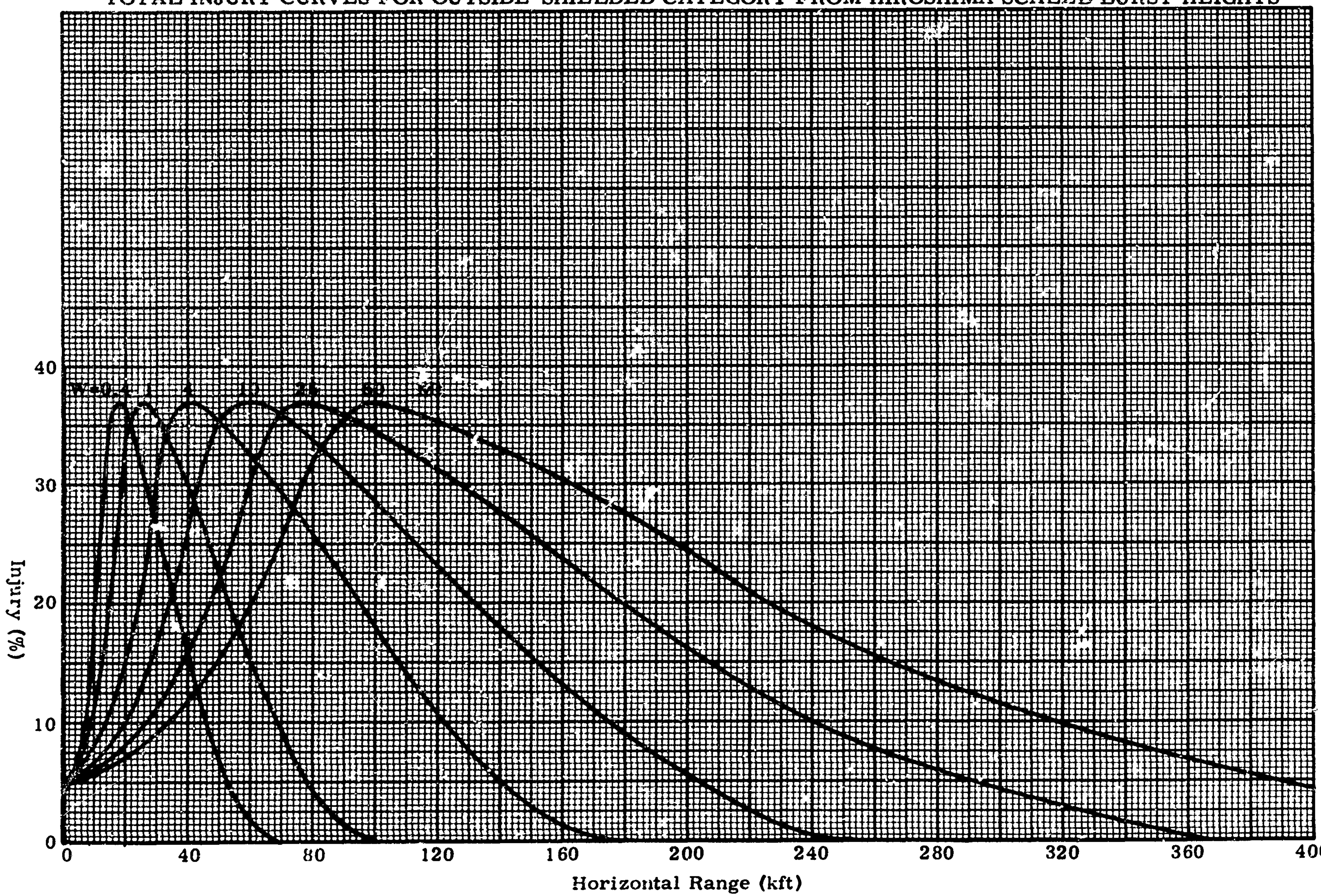


FIG. 23

TOTAL INJURY CURVES FOR OUTSIDE-UNSHIELDED CATEGORY FROM HIROSHIMA SCALED BURST HEIGHTS

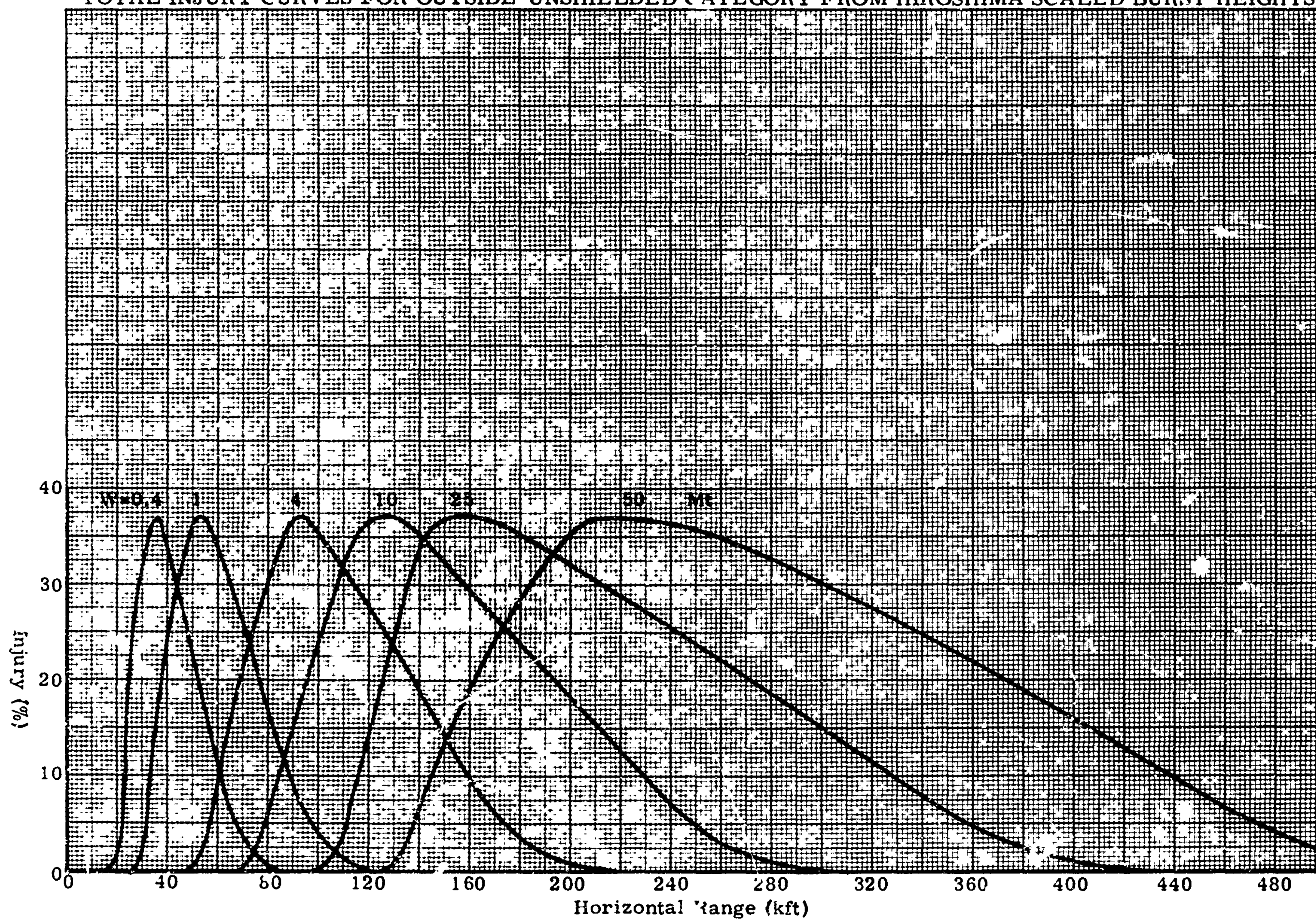


FIG. 24

TOTAL MORTALITY CURVES FOR CATEGORY 1 FROM SURFACE BURSTS

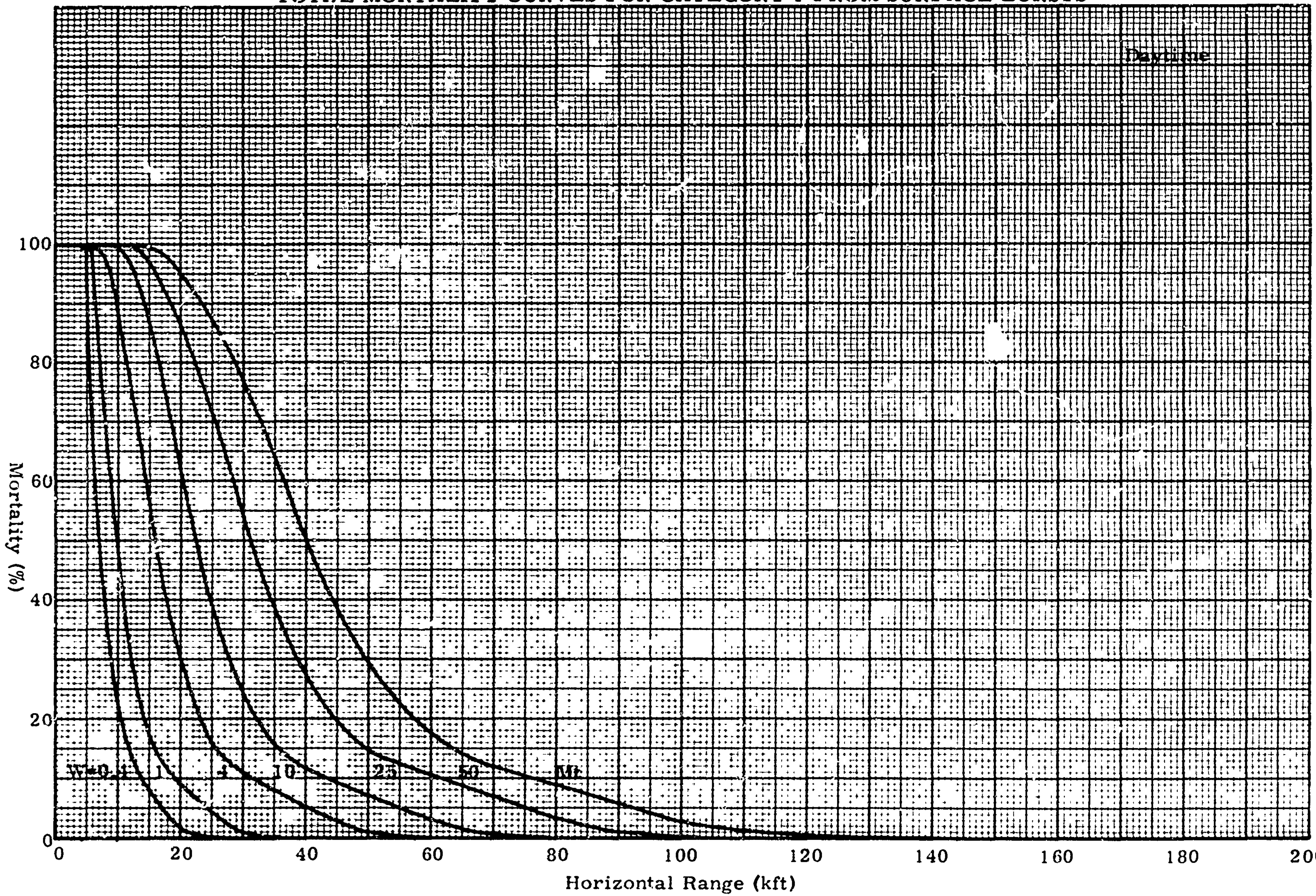


FIG. 25

TOTAL MORTALITY CURVES FOR CATEGORIES 2 AND 5 FROM SURFACE BURSTS

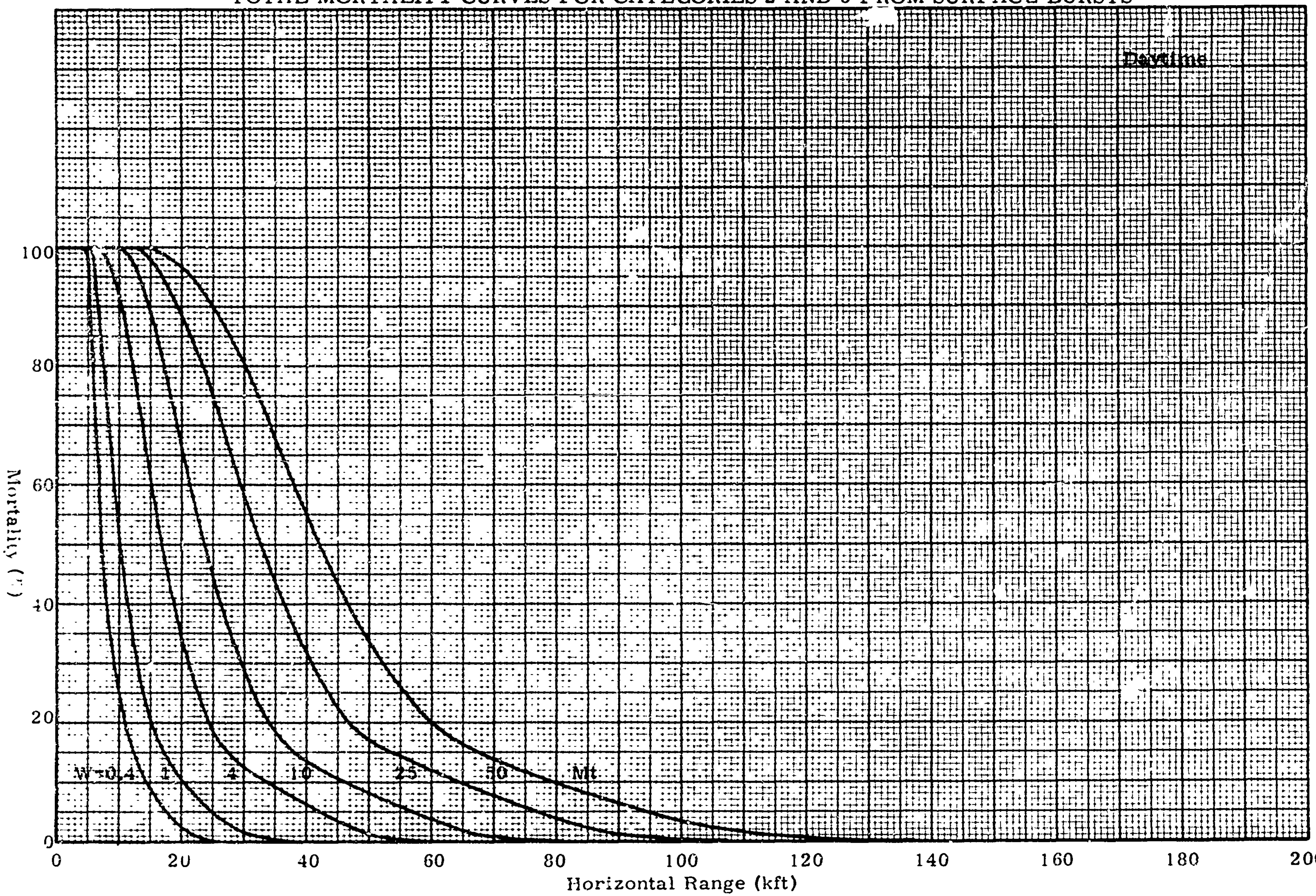


FIG. 26

TOTAL MORTALITY CURVES FOR CATEGORY 3 FROM SURFACE BURSTS

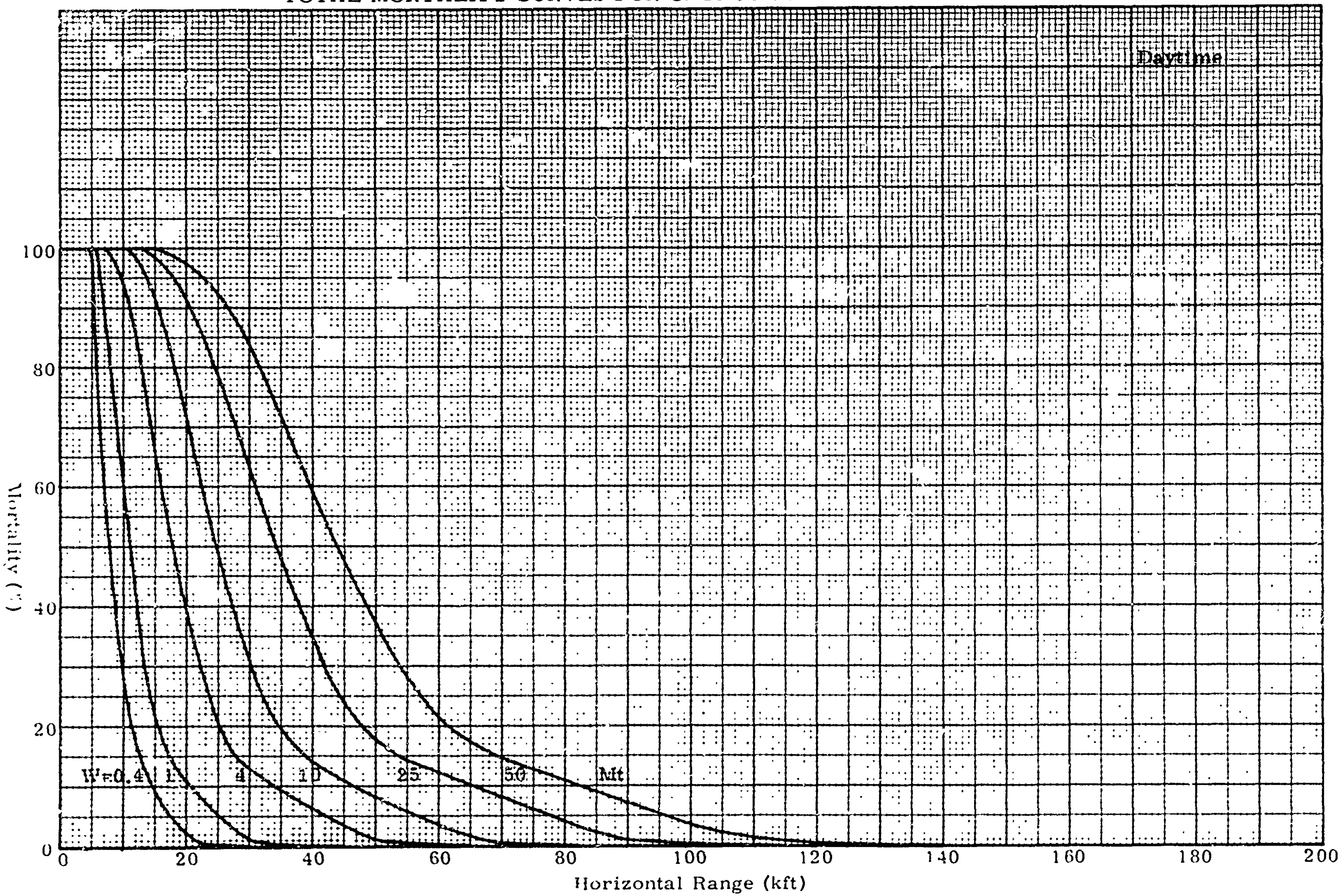


FIG. 27
TOTAL MORTALITY CURVES FOR CATEGORY 4 FROM SURFACE BURSTS

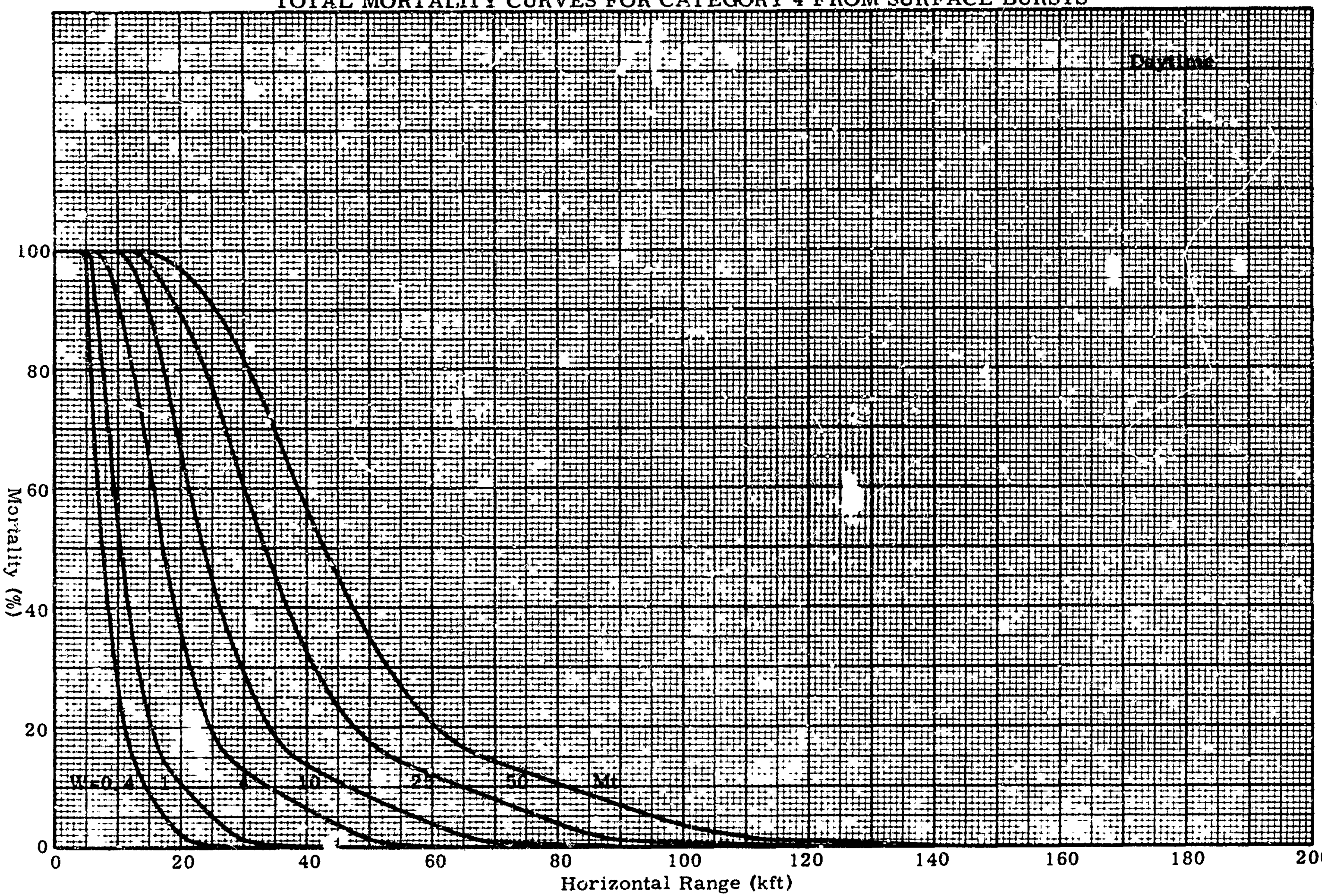


FIG. 28

FIG. 28

TOTAL MORTALITY CURVES FOR CATEGORY 6 FROM SURFACE BURSTS

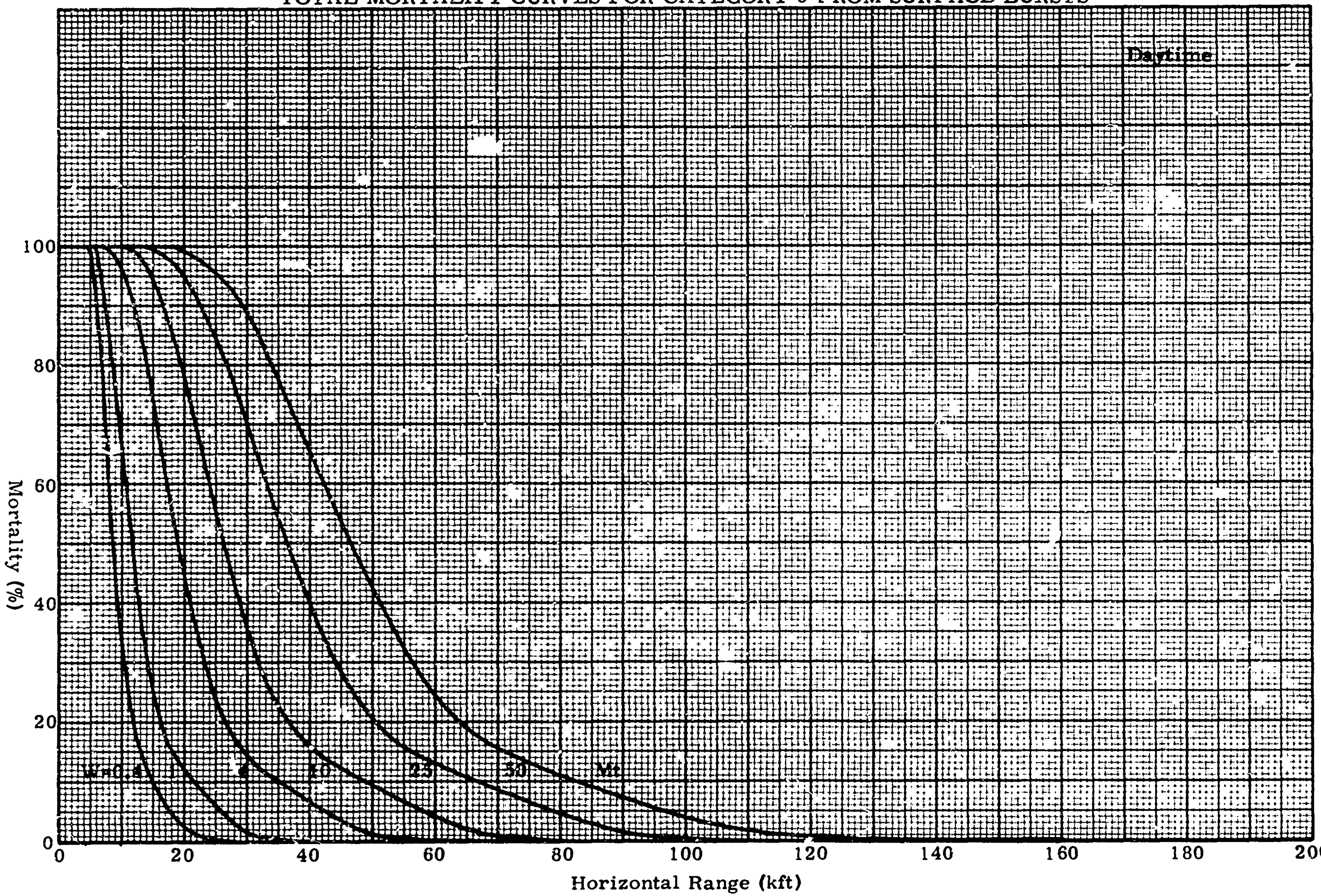


FIG. 29

TOTAL MORTALITY CURVES FOR CATEGORY 7 FROM SURFACE BURSTS

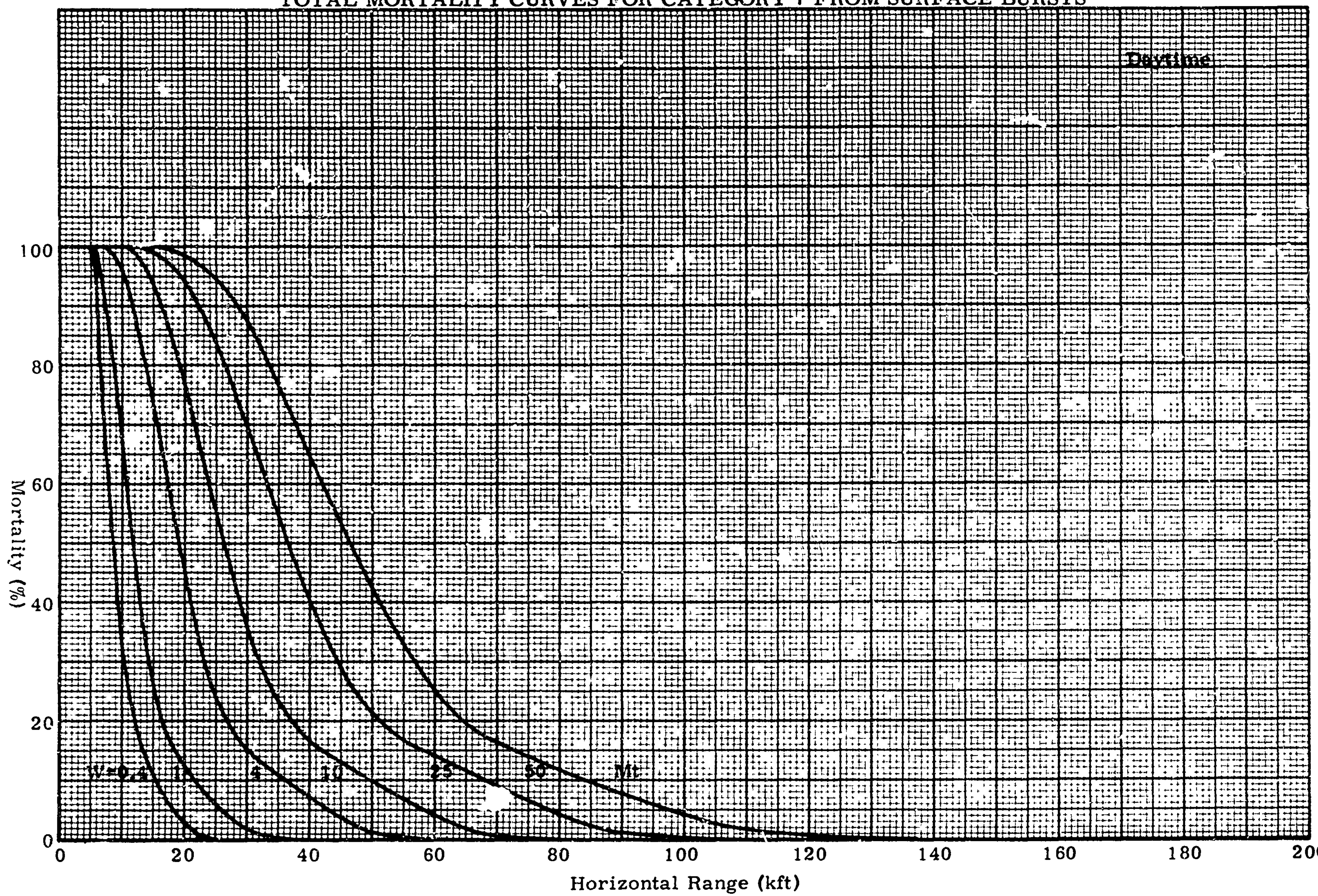


FIG. 30

TOTAL MORTALITY CURVES FOR CATEGORY 8 FROM SURFACE BURSTS

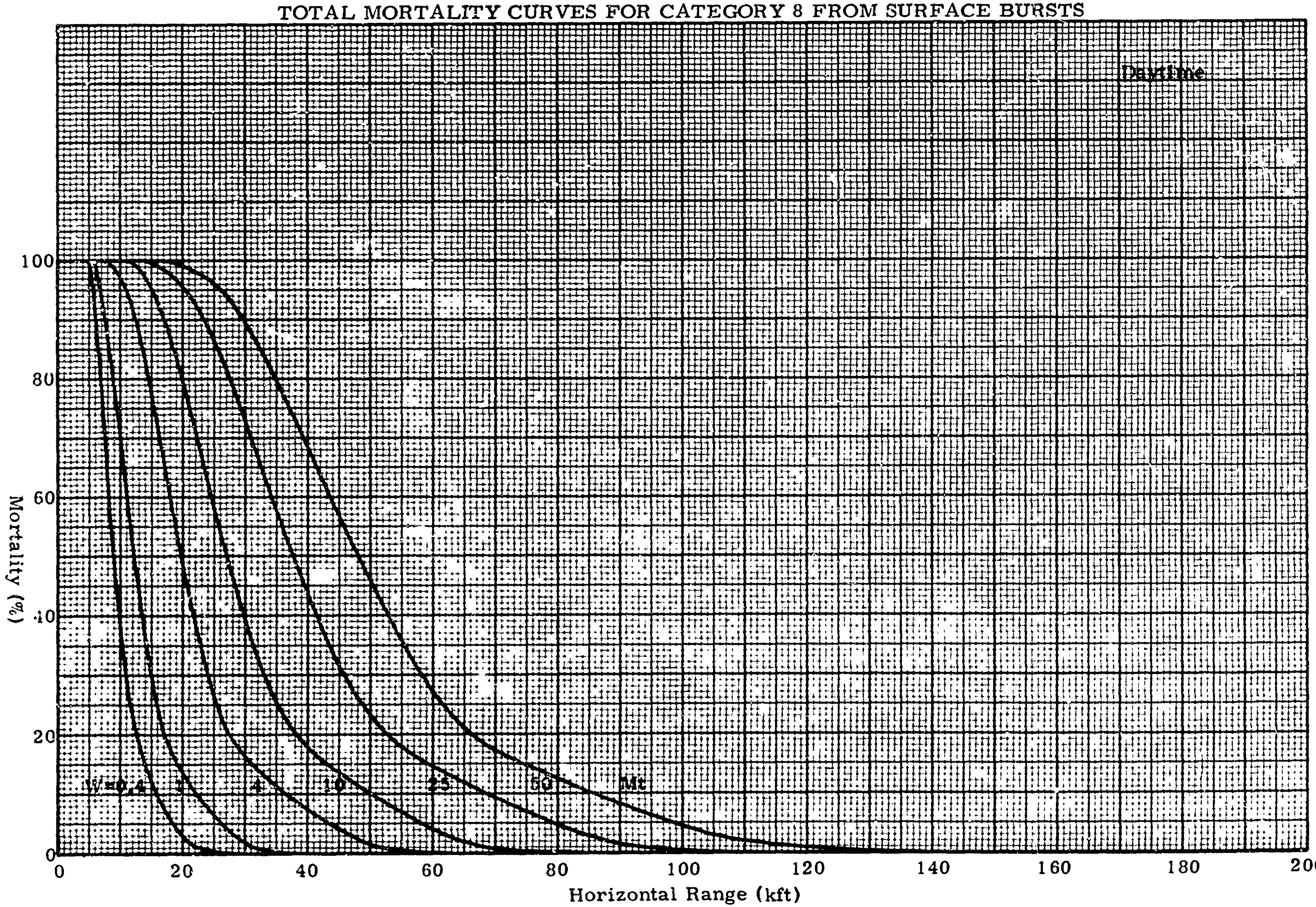


FIG. 31

TOTAL MORTALITY CURVES FOR CATEGORY 9 FROM SURFACE BURSTS

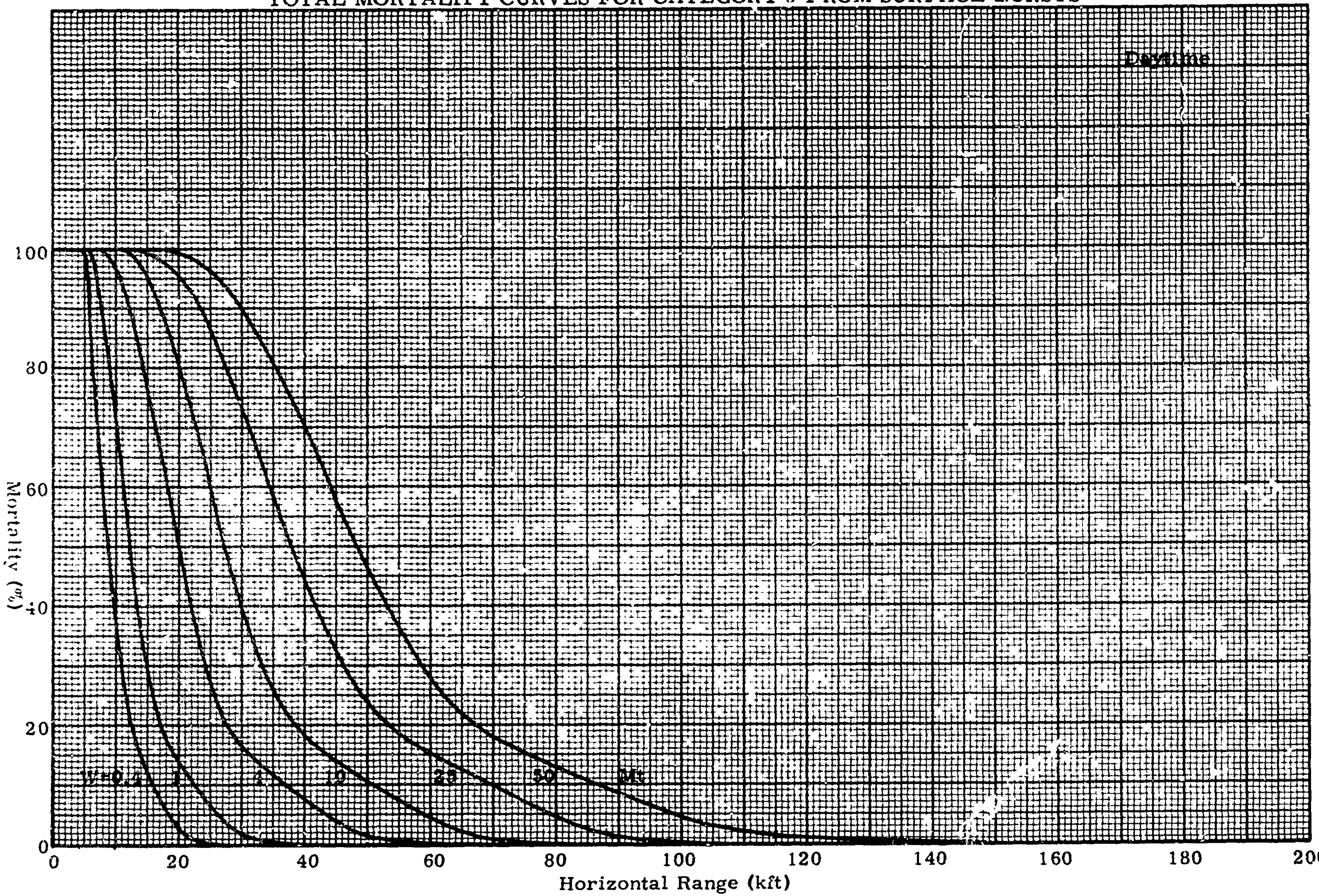


FIG. 32

TOTAL MORTALITY CURVES FOR CATEGORY 10 FROM SURFACE BURSTS

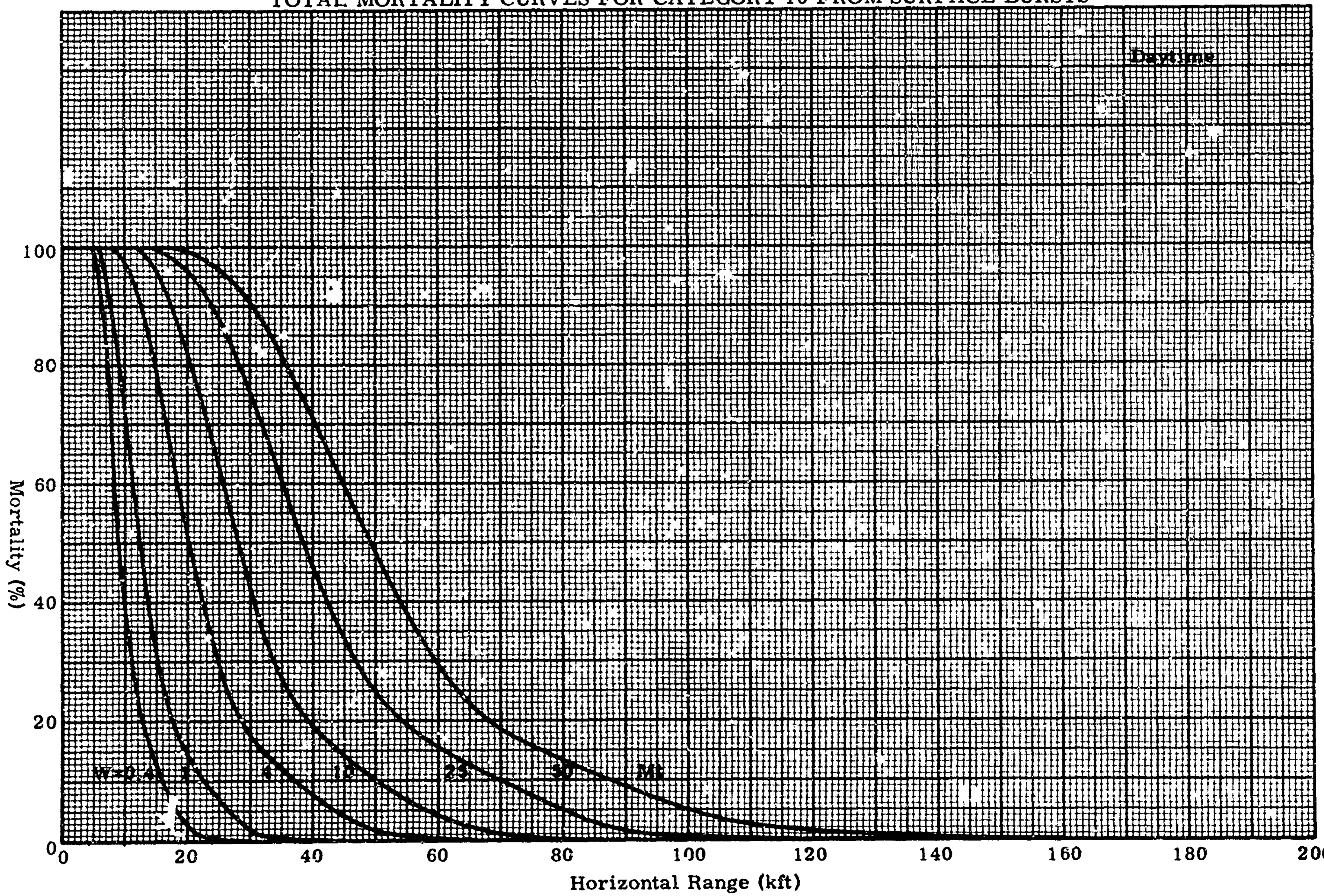


FIG. 33

TOTAL INJURY CURVES FOR CATEGORY 1 FROM SURFACE BURSTS

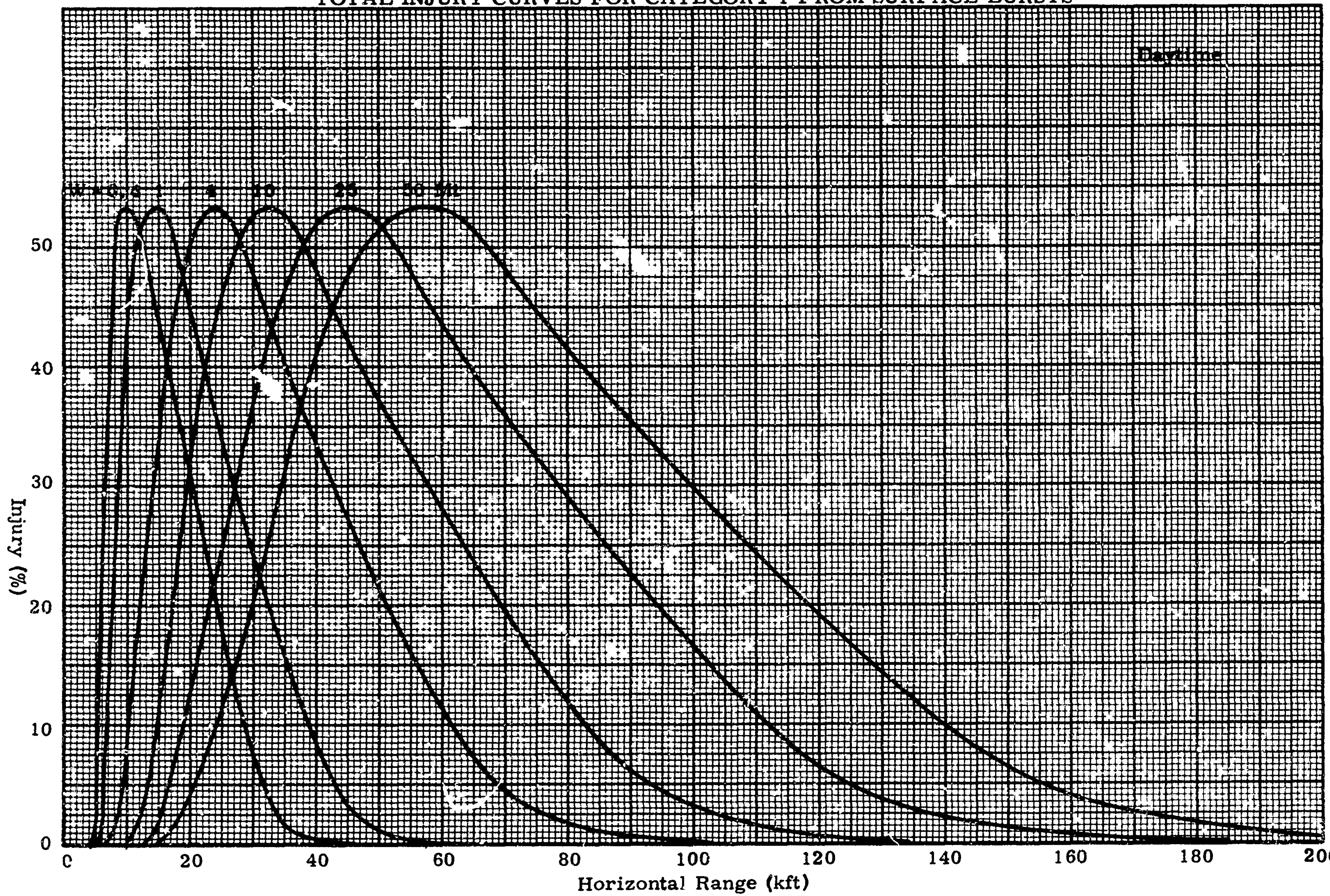


FIG. 34

TOTAL INJURY CURVES FOR CATEGORIES 2 AND 5 FROM SURFACE BURSTS

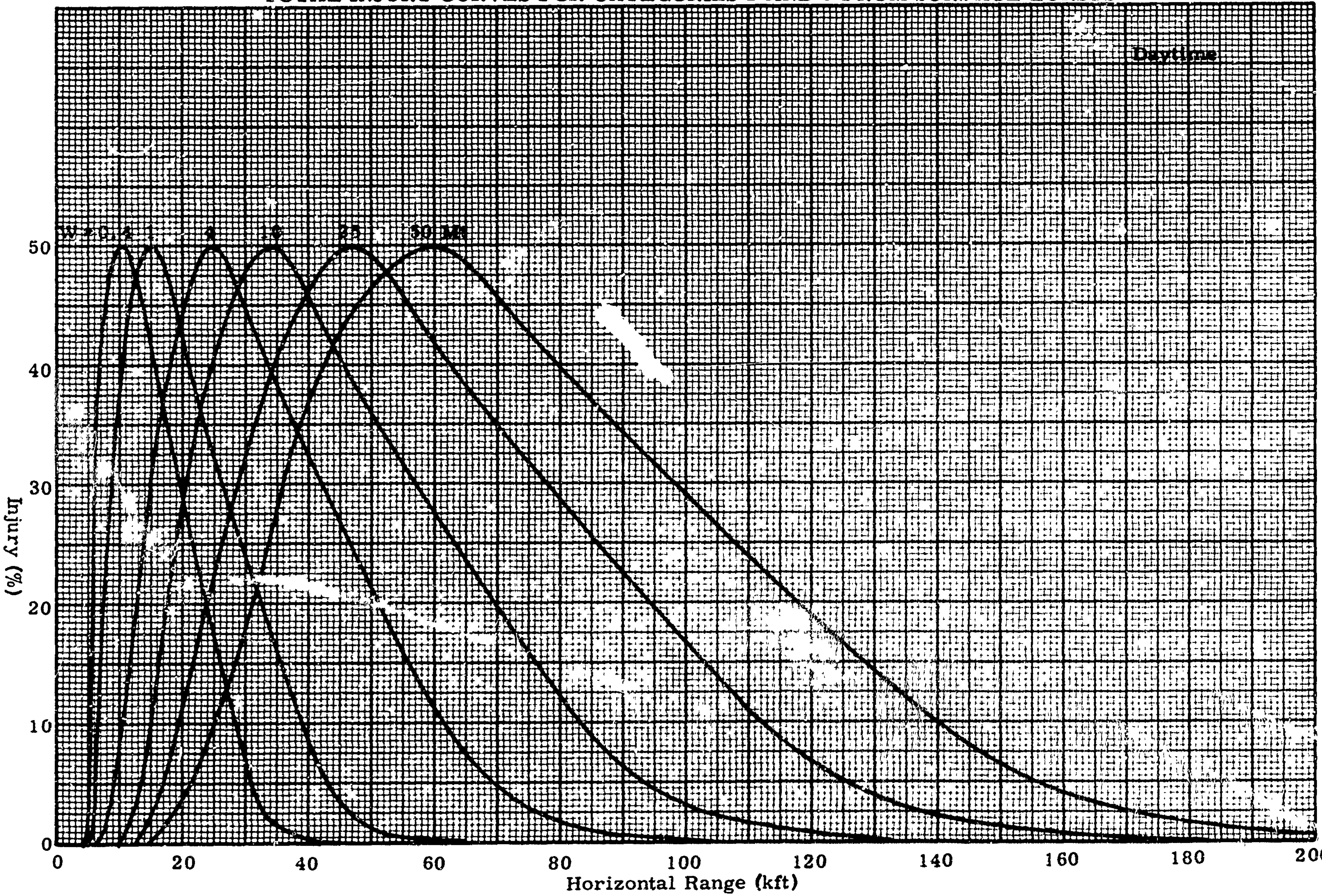
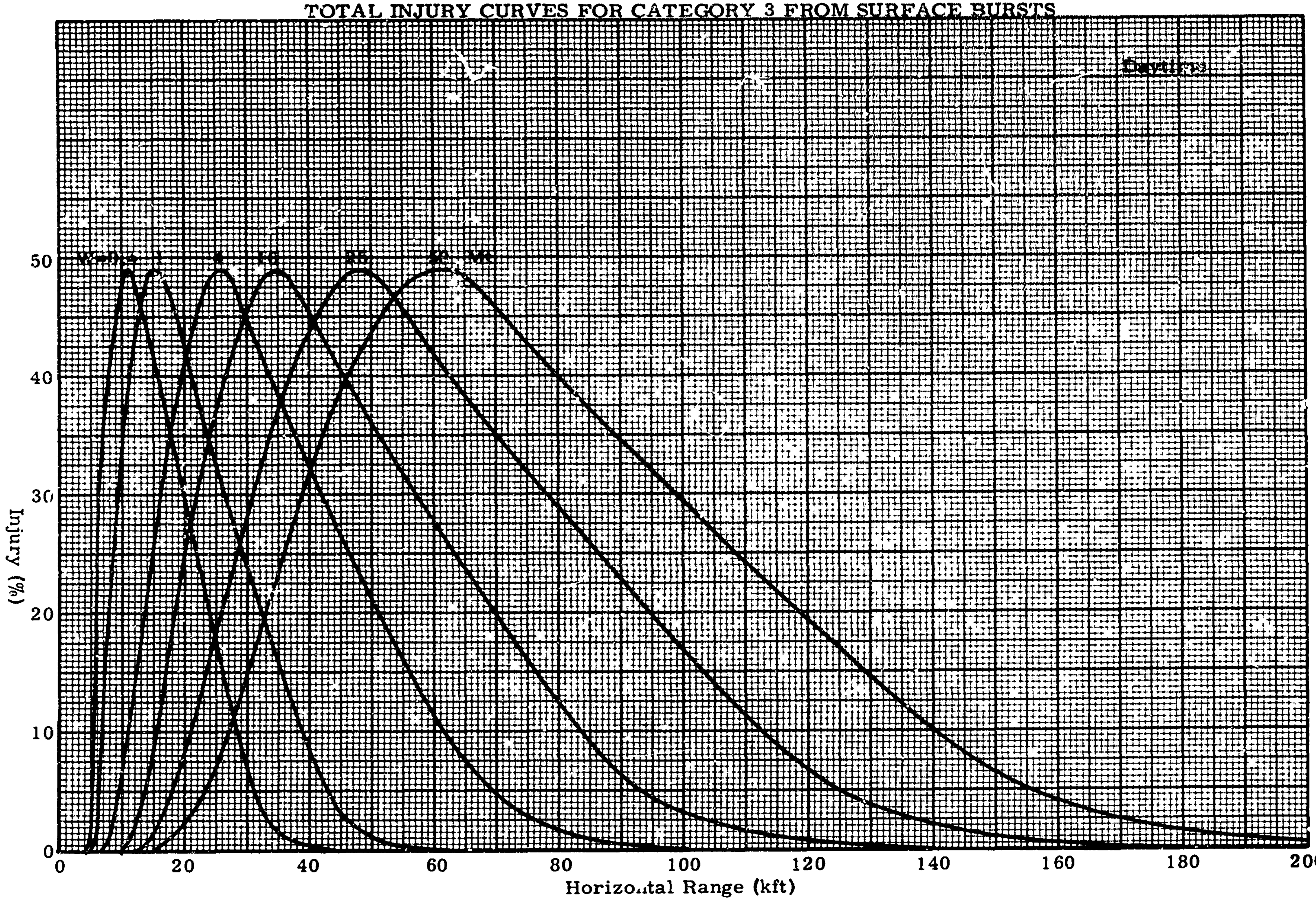


FIG. 35
TOTAL INJURY CURVES FOR CATEGORY 3 FROM SURFACE BURSTS



Horizontal Range (kft)

FIG. 36

TOTAL INJURY CURVES FOR CATEGORY 4 FROM SURFACE BURSTS

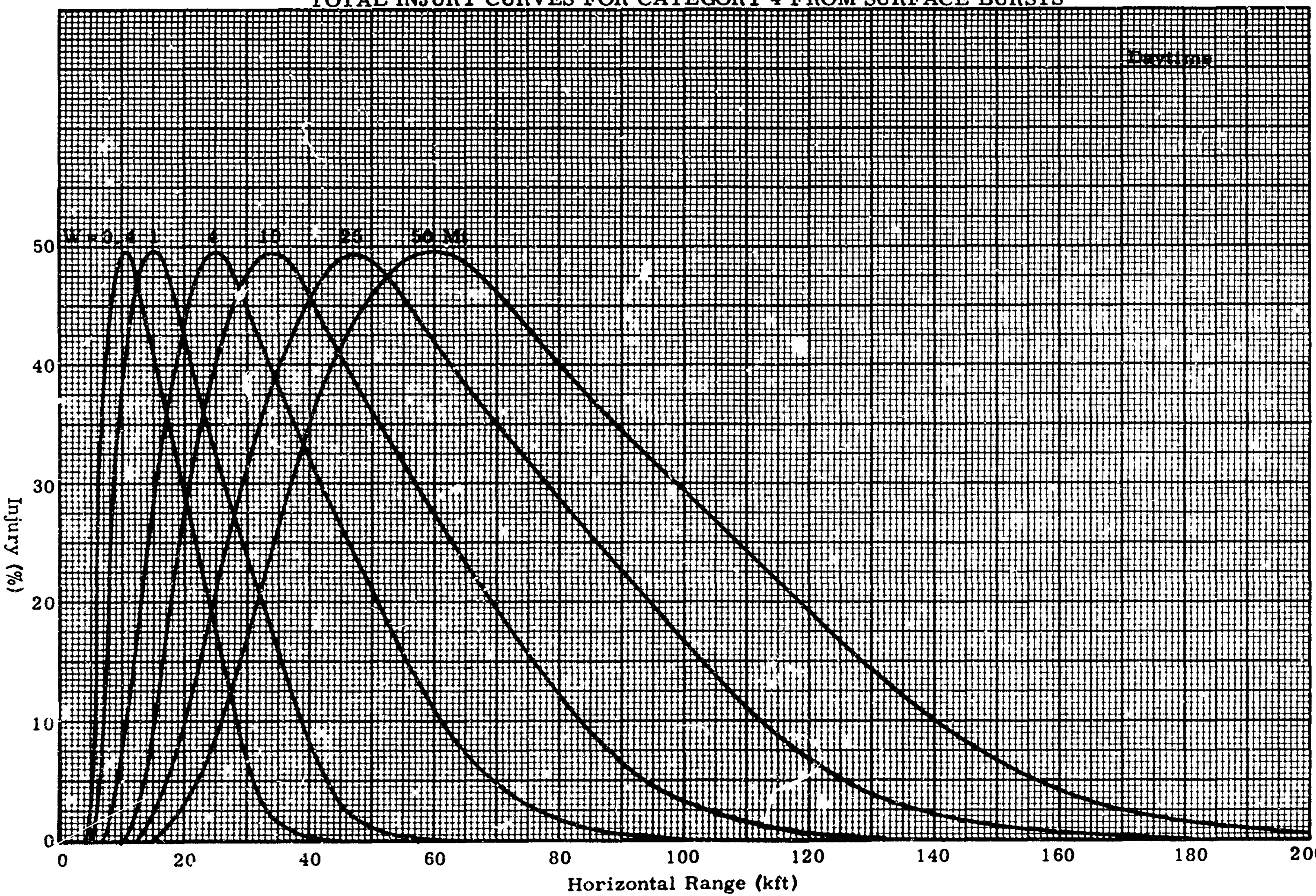


FIG. 37

TOTAL INJURY CURVES FOR CATEGORY 6 FROM SURFACE BURSTS

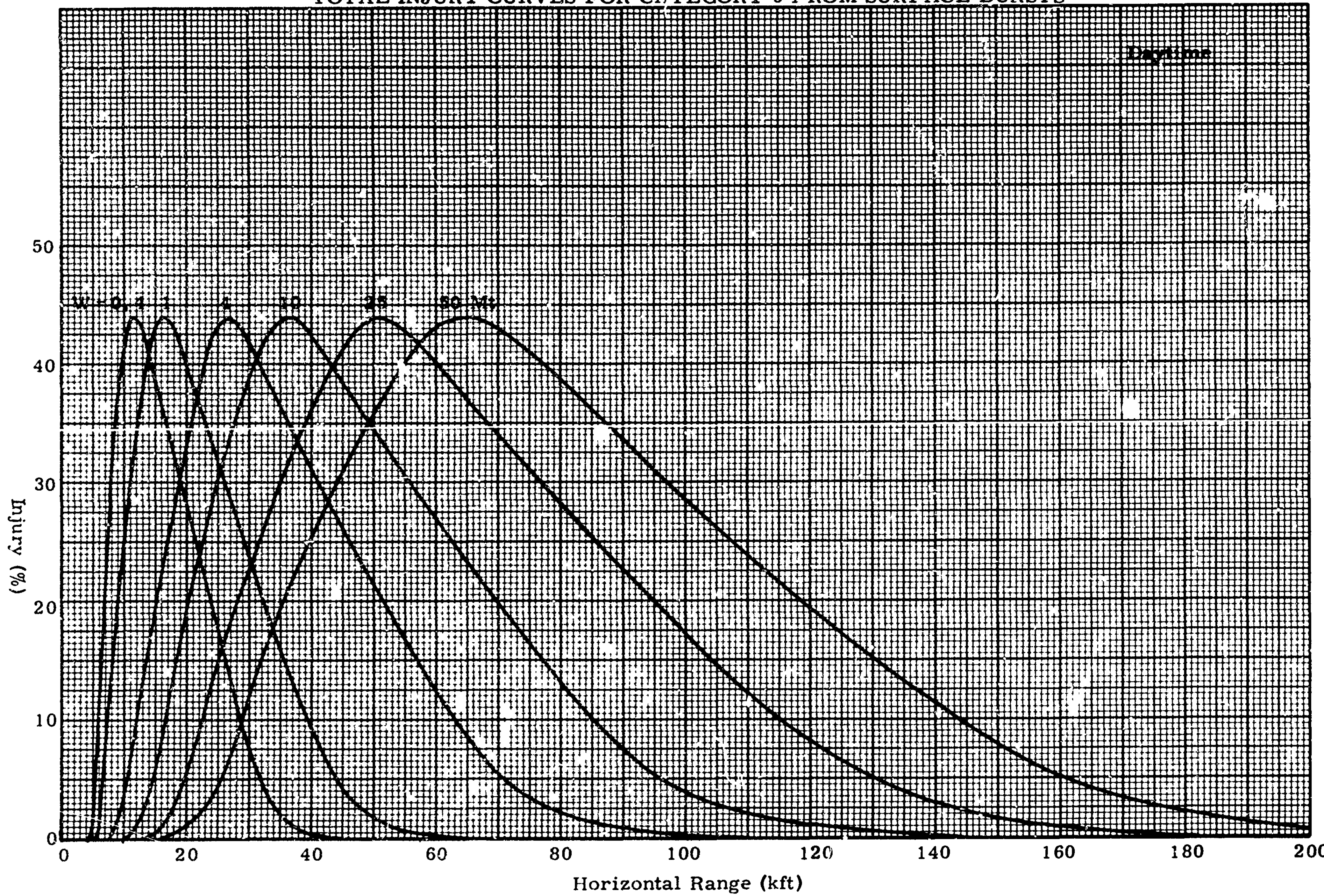


FIG. 38
TOTAL INJURY CURVES FOR CATEGORY 7 FROM SURFACE BURSTS

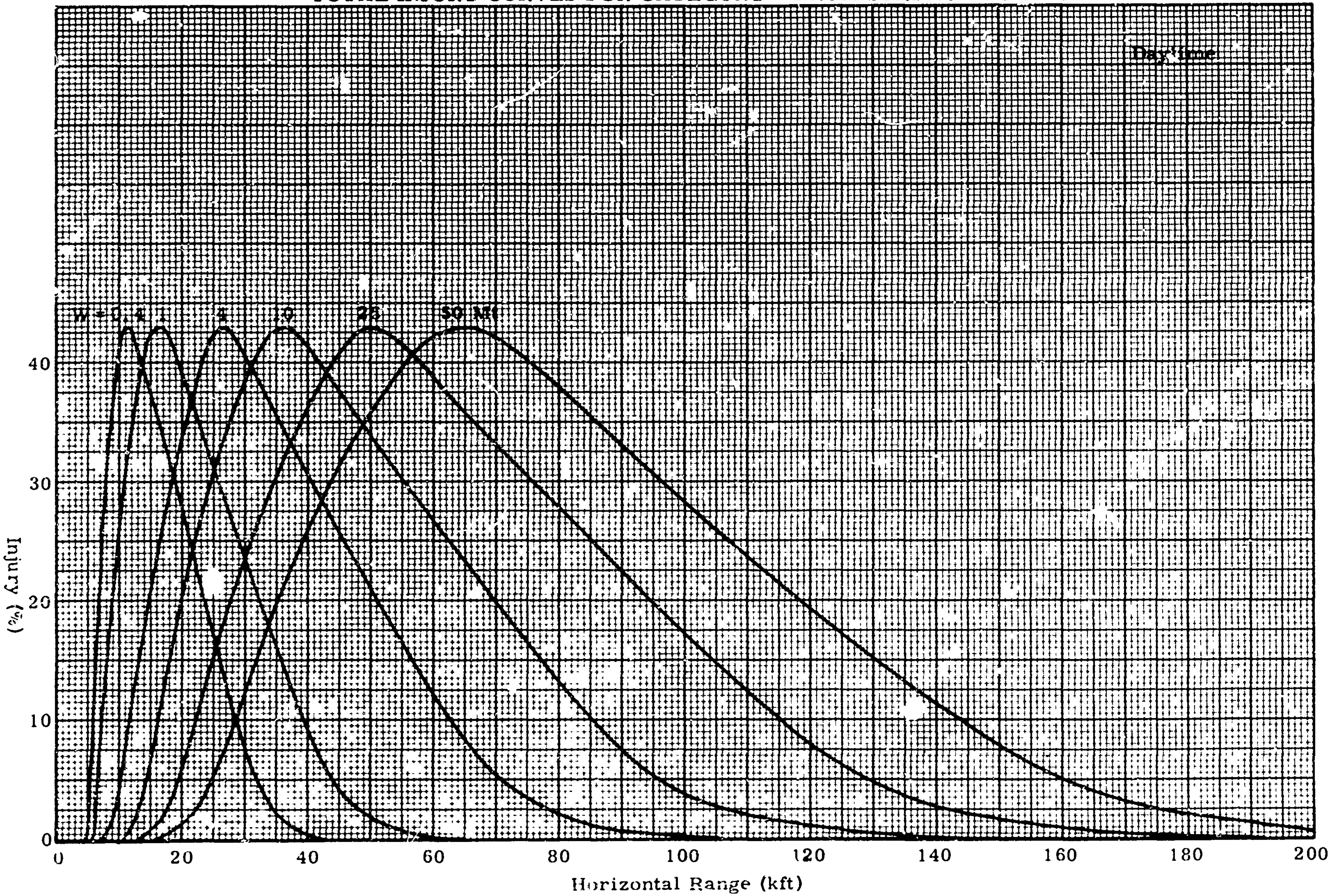


FIG. 39

TOTAL INJURY CURVES FOR CATEGORY 8 FROM SURFACE BURSTS

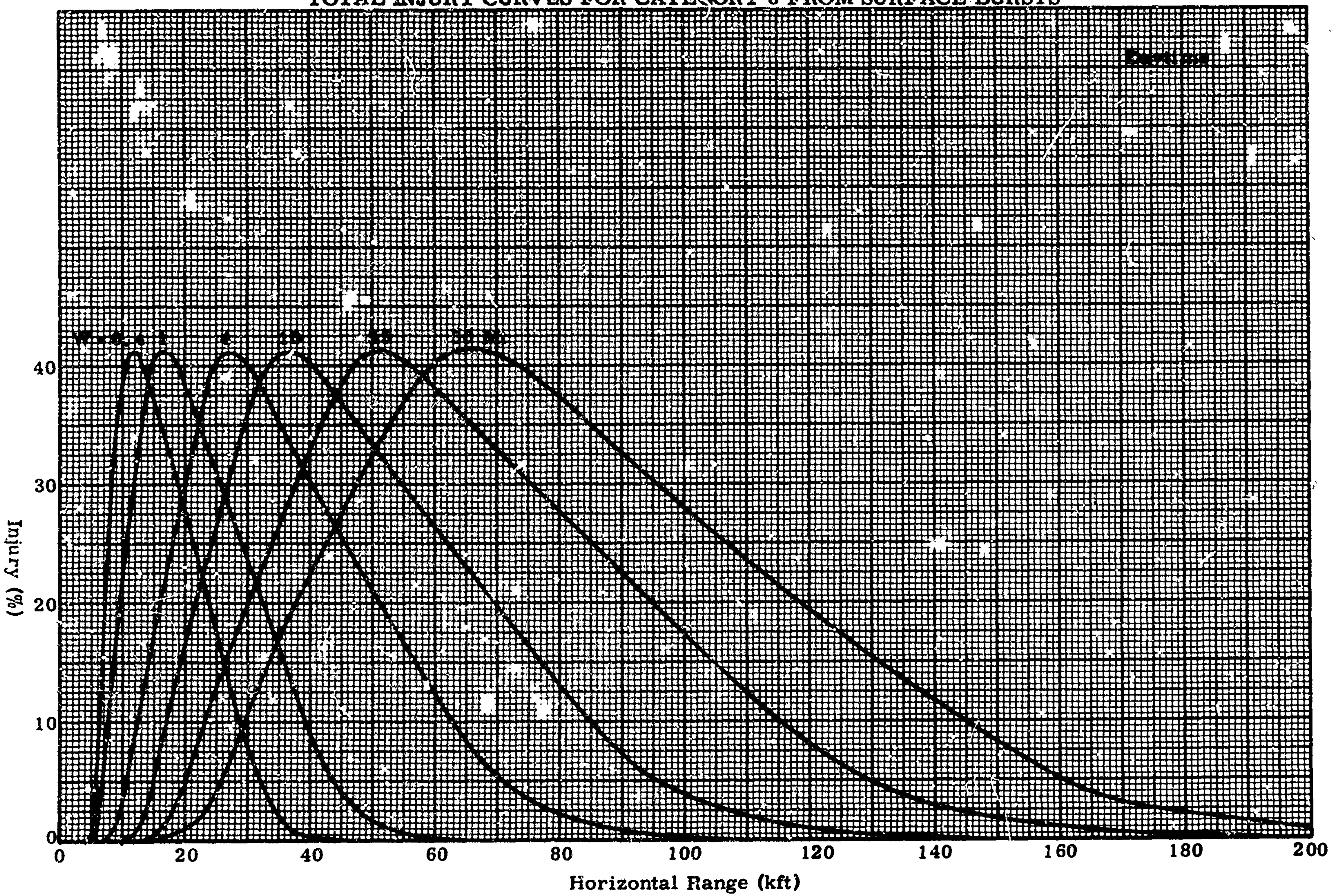


FIG. 40

TOTAL INJURY CURVES FOR CATEGORY 9 FROM SURFACE BURSTS

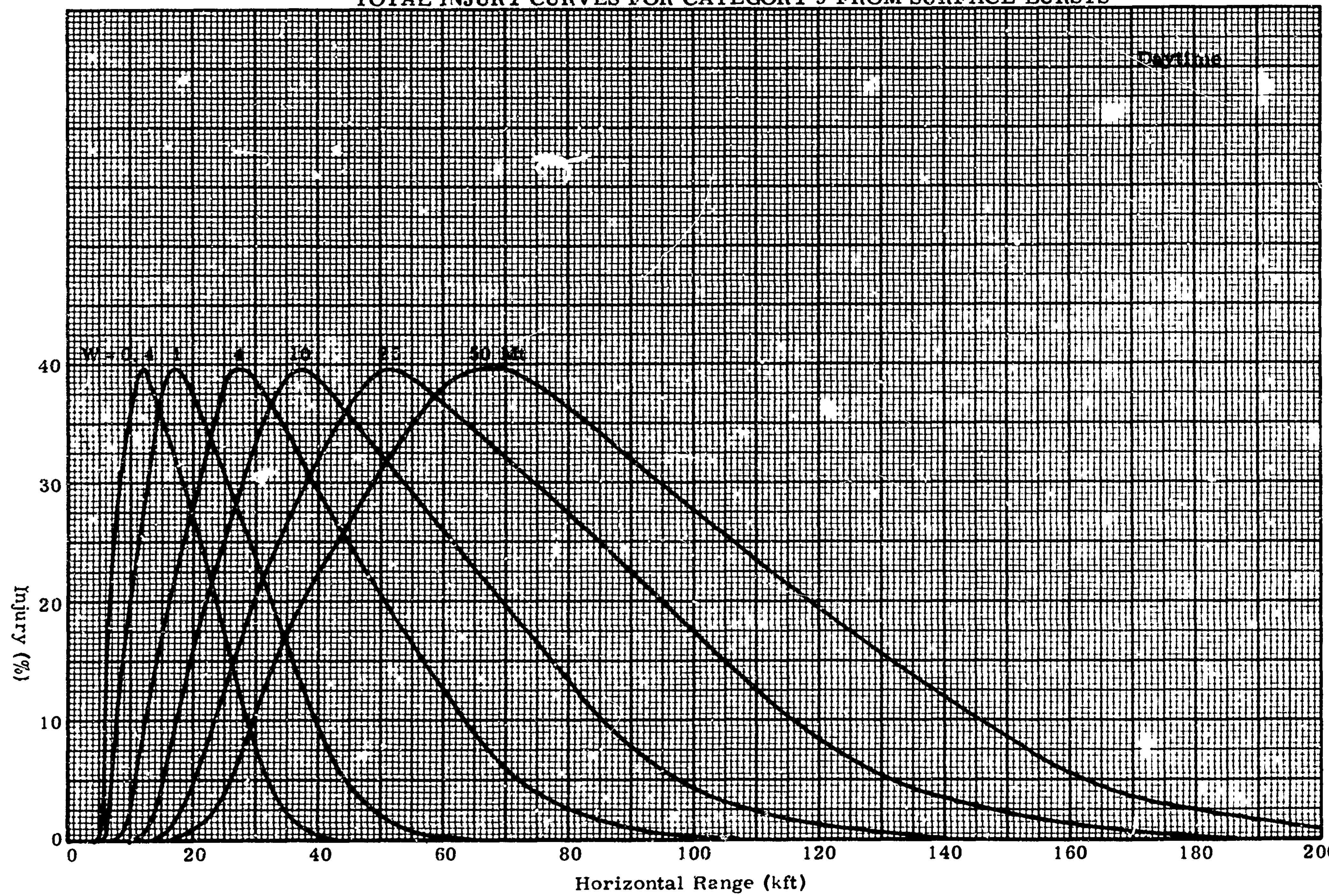


FIG. 41

TOTAL INJURY CURVES FOR CATEGORY 10 FROM SURFACE BURSTS

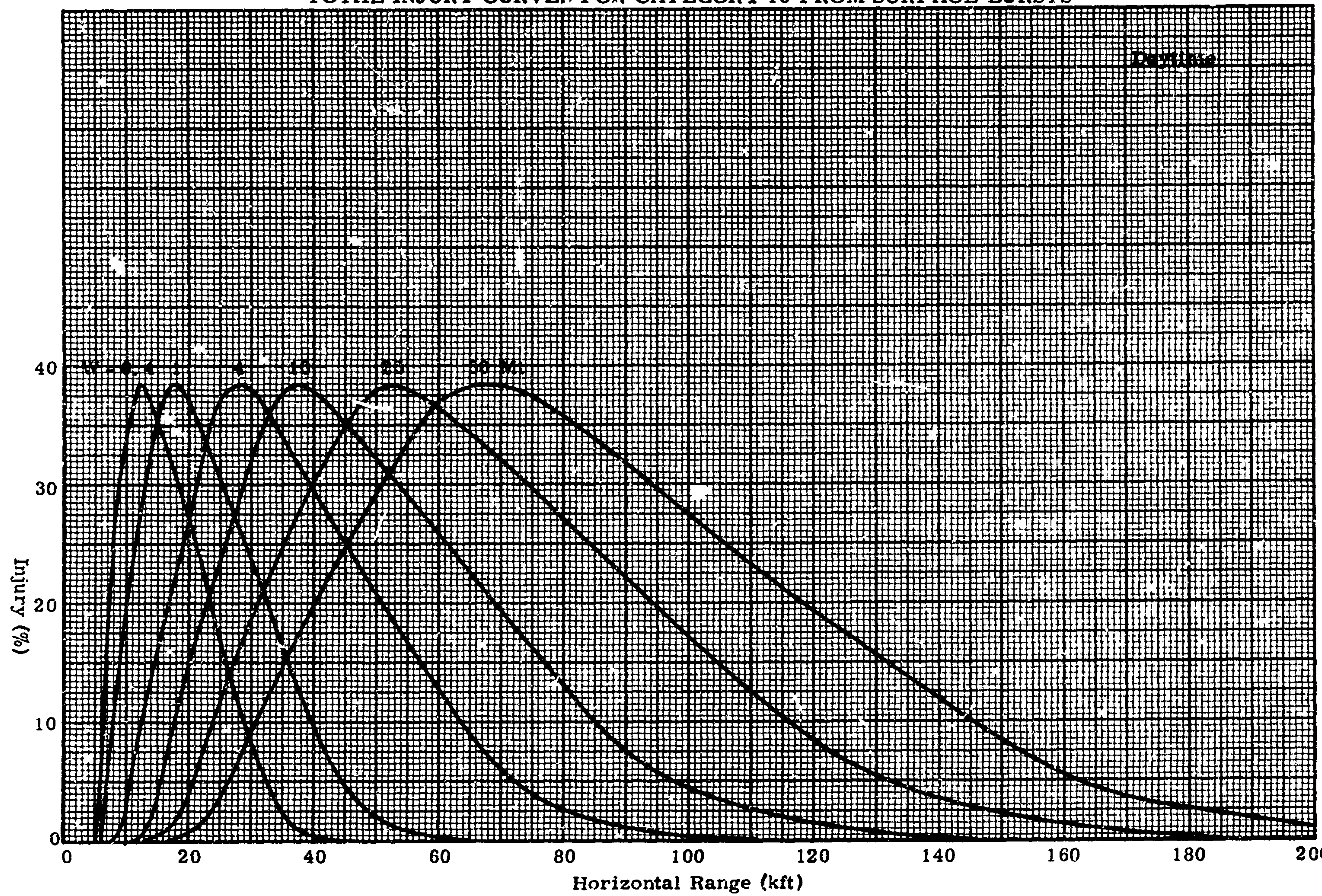


FIG. 42

TOTAL MORTALITY CURVES FOR CATEGORY 1 FROM HIROSHIMA SCALED BURST HEIGHTS

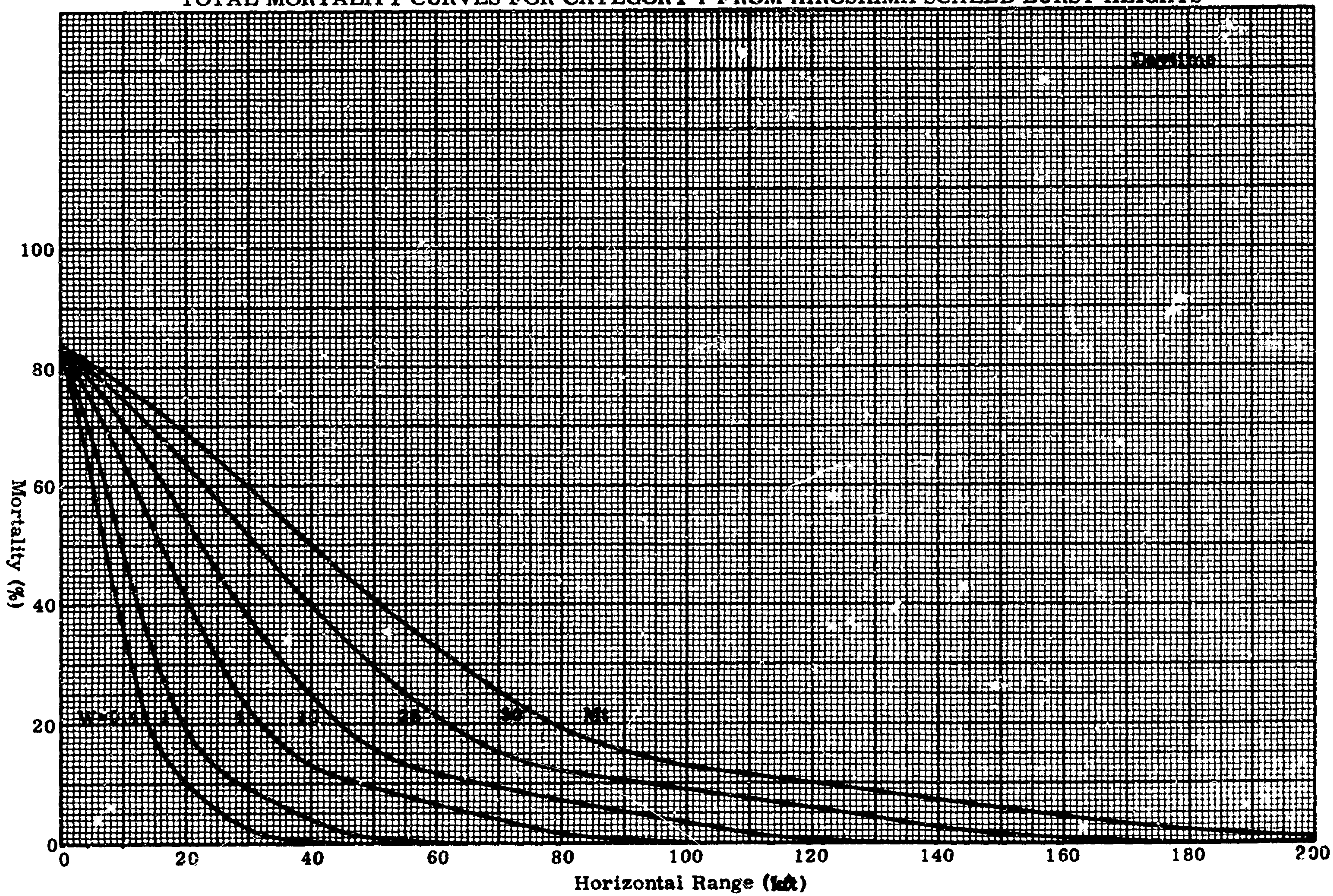


FIG. 43

TOTAL MORTALITY CURVES FOR CATEGORIES 2 AND 5 FROM HIROSHIMA SCALED BURST HEIGHTS

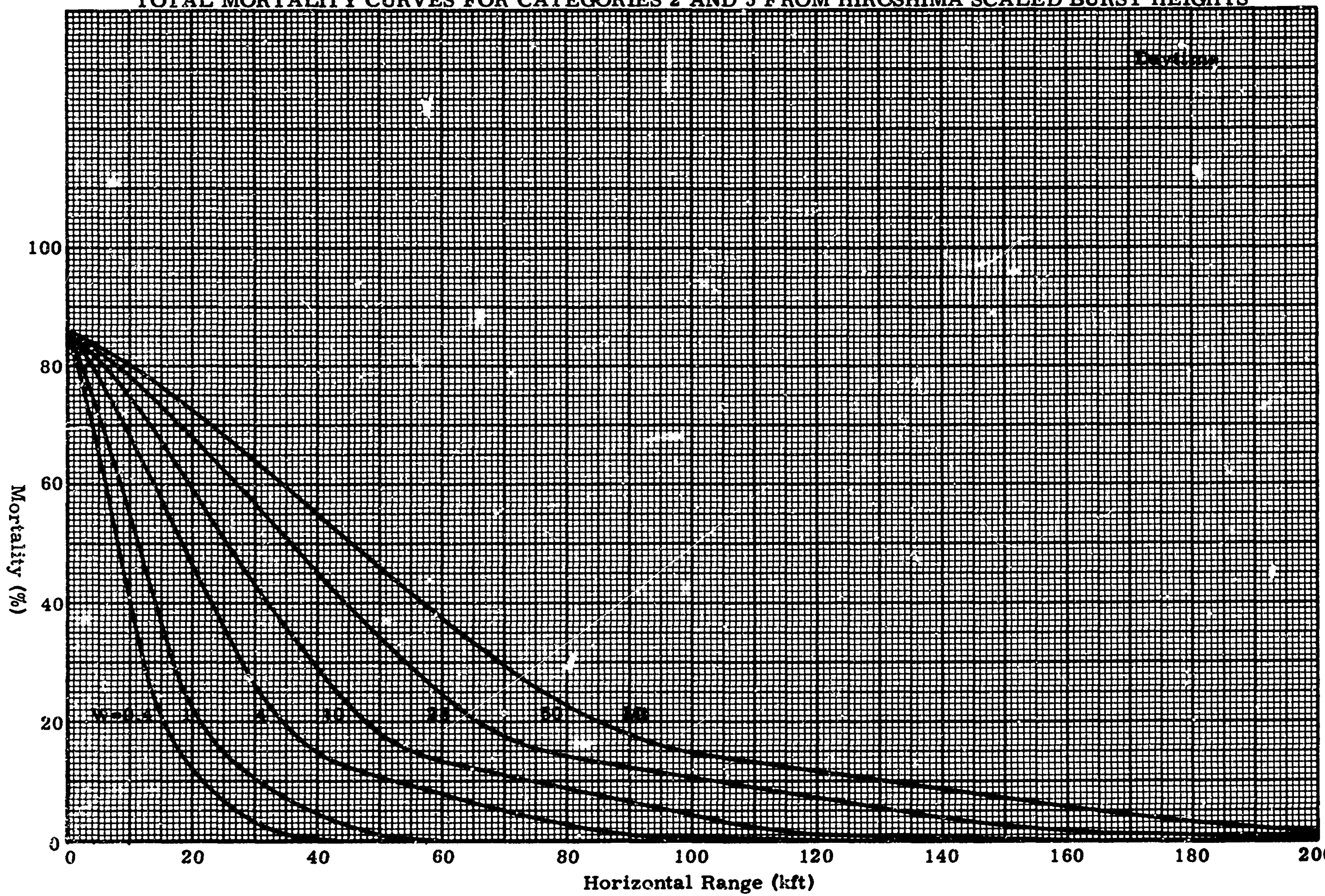


FIG. 44

TOTAL MORTALITY CURVES FOR CATEGORY 3 FROM HIROSHIMA SCALED BURST HEIGHTS

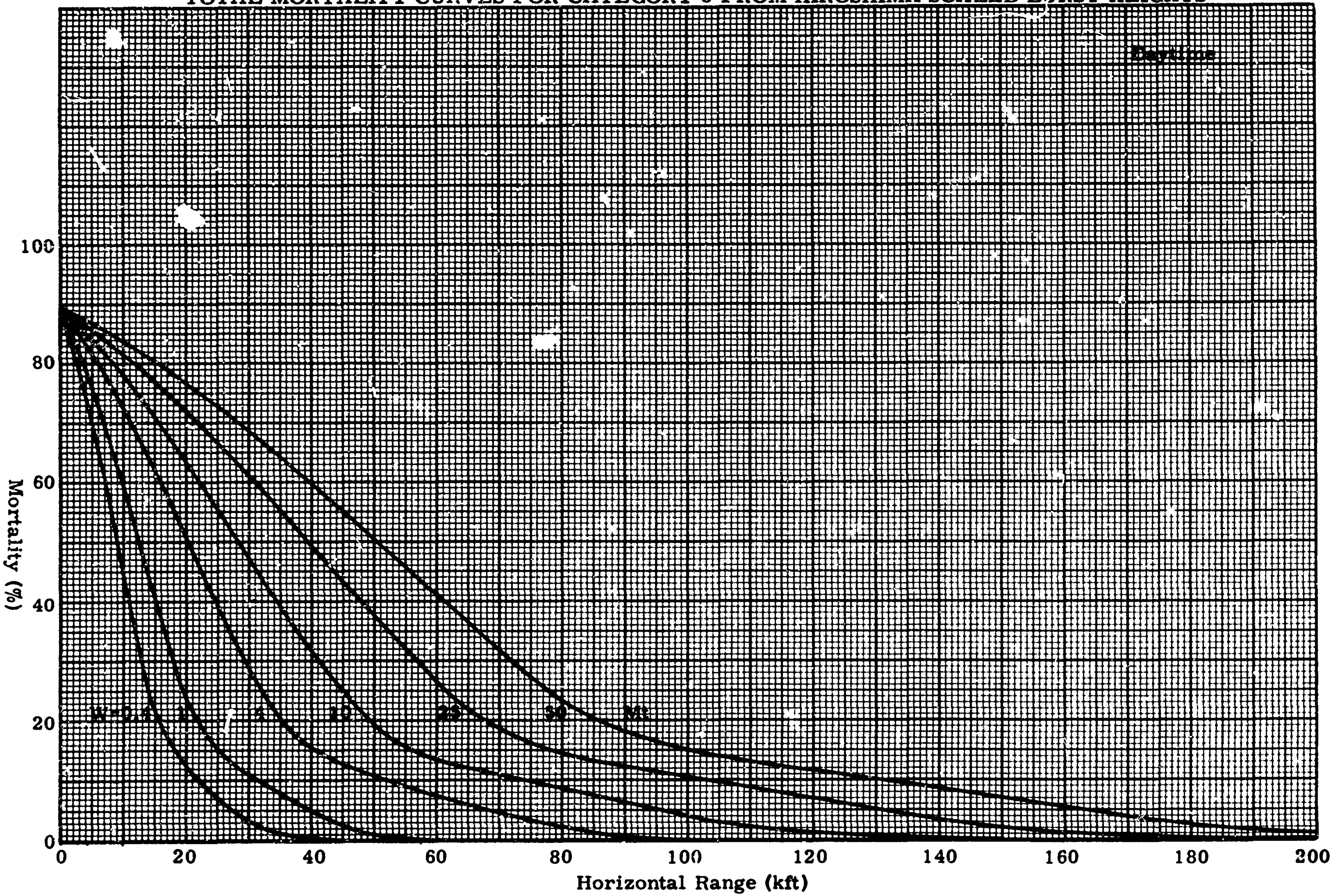


FIG. 45

TOTAL MORTALITY CURVES FOR CATEGORY 4 FROM HIROSHIMA SCALED BURST HEIGHTS

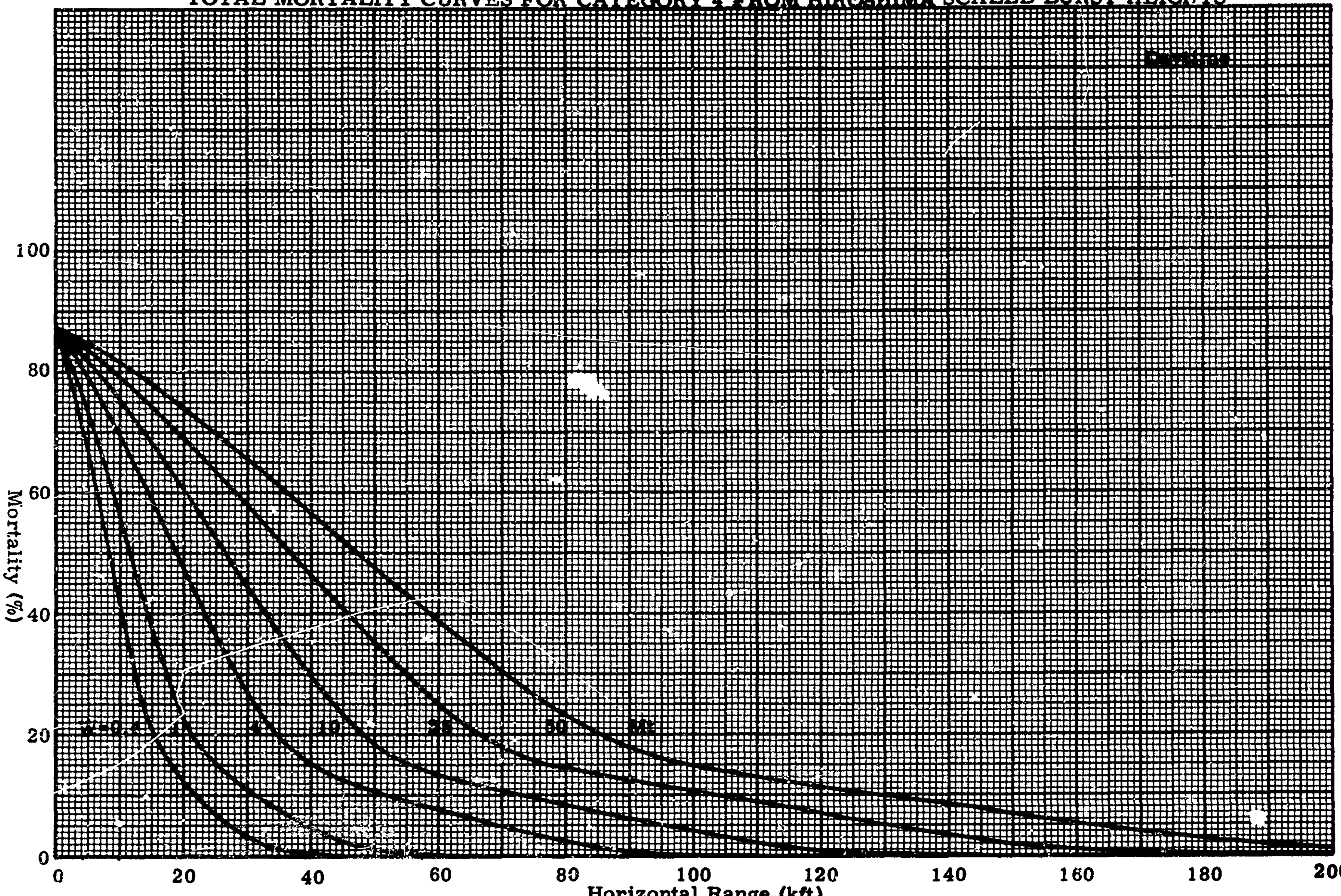


FIG. 46

TOTAL MORTALITY CURVES FOR CATEGORY 6 FROM HIROSHIMA SCALED BURST HEIGHTS

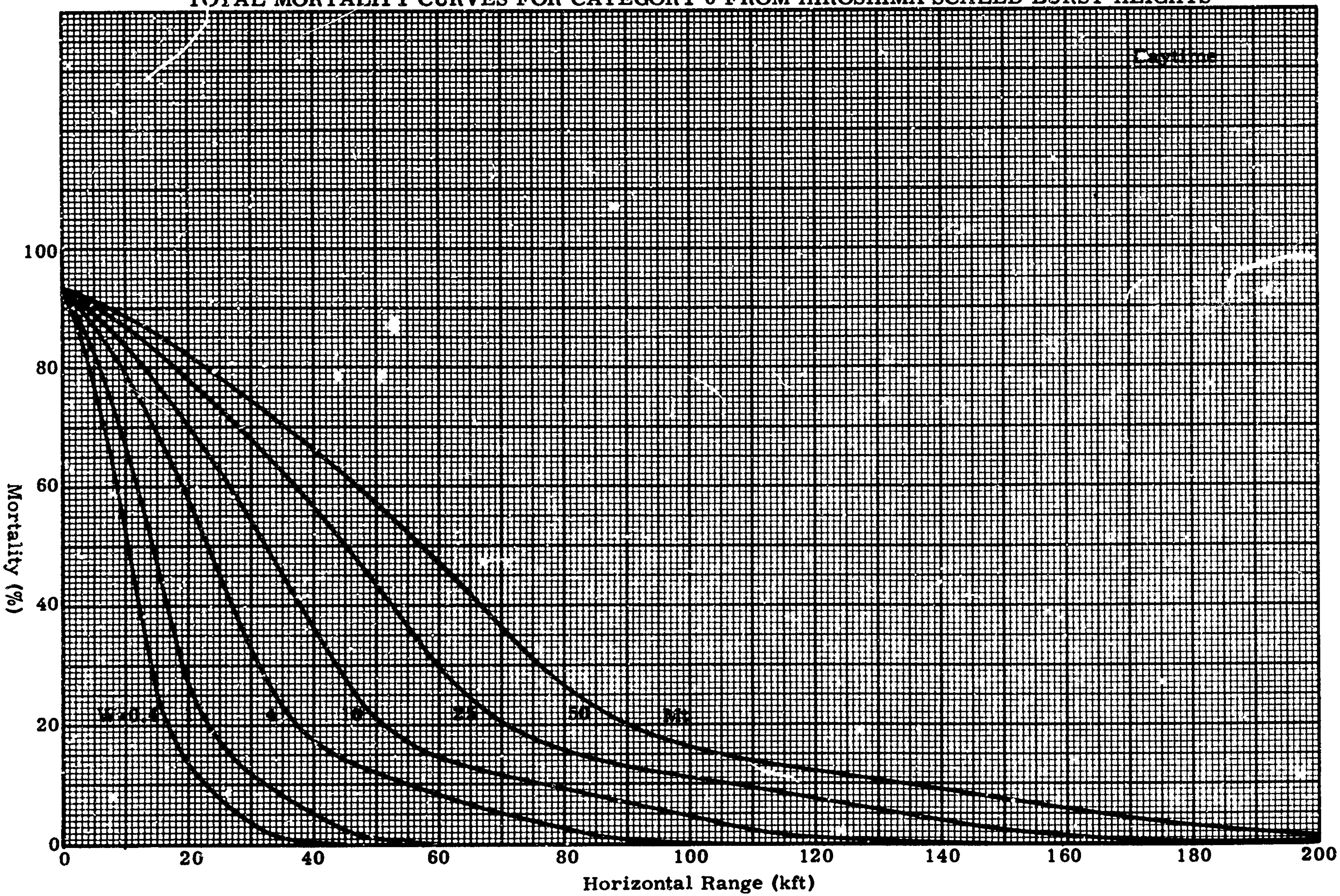


FIG. 47

TOTAL MORTALITY CURVES FOR CATEGORY 7 FROM HIROSHIMA SCALED BURST HEIGHTS

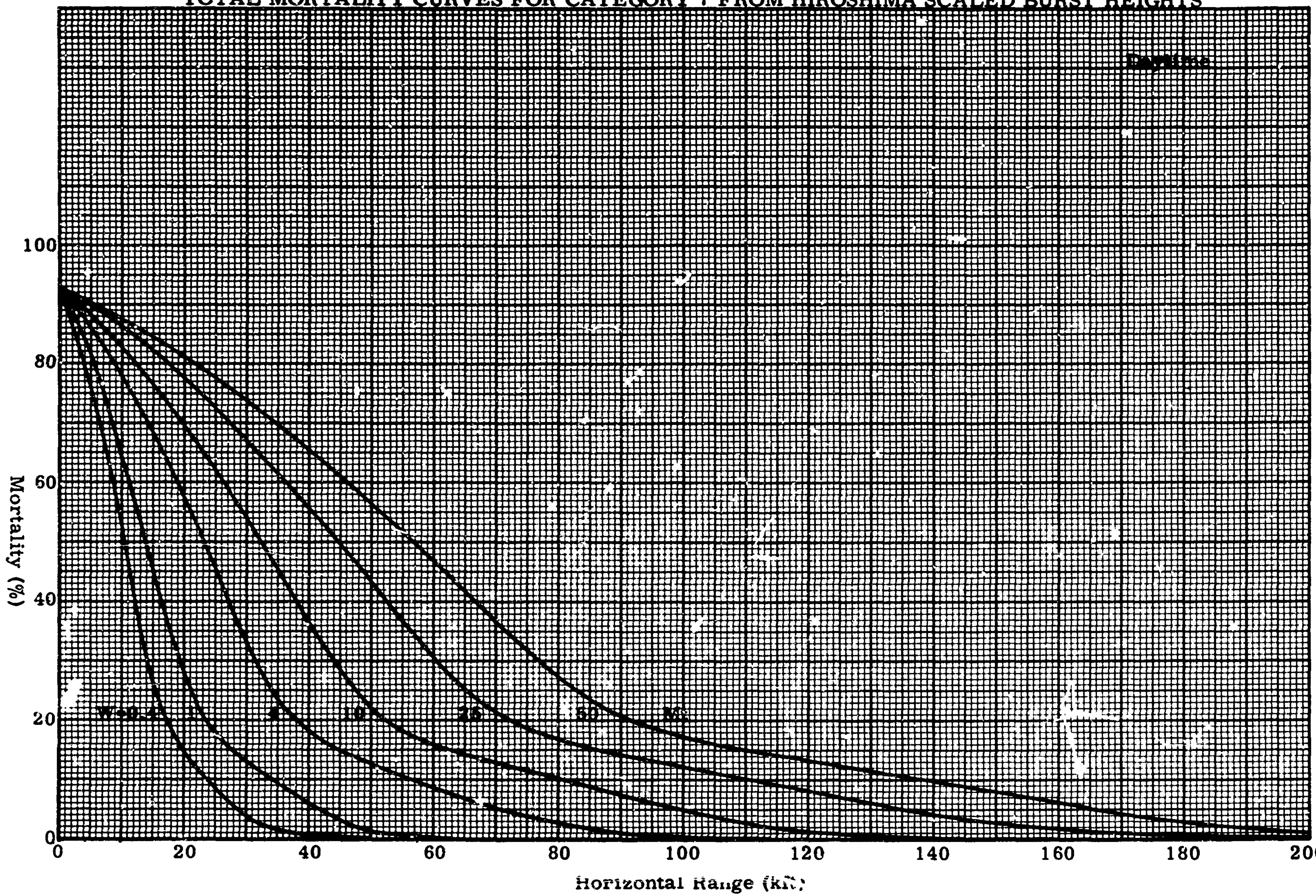


FIG. 48

TOTAL MORTALITY CURVES FOR CATEGORY 8 FROM HIROSHIMA SCALED BURST HEIGHTS

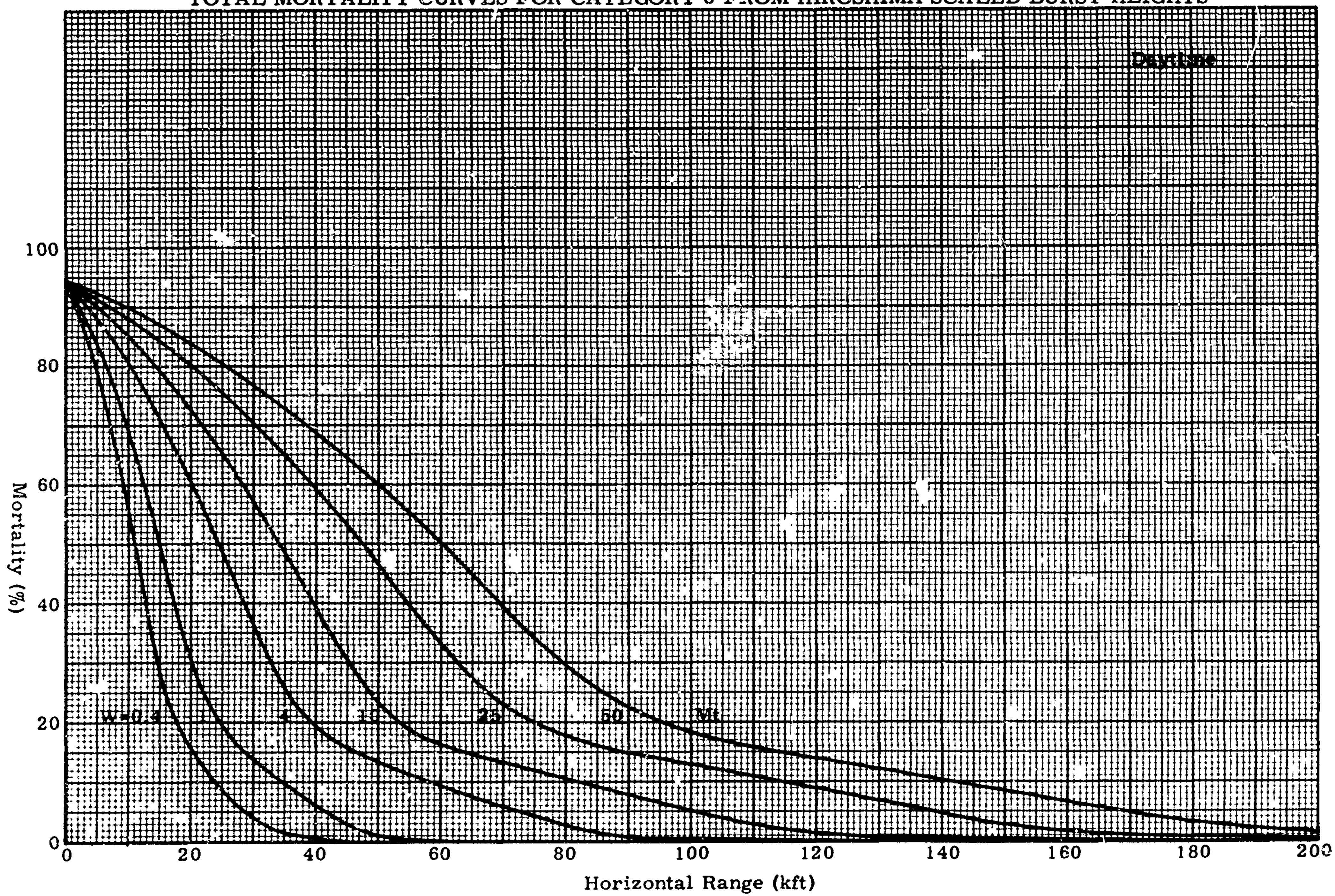


FIG. 49

TOTAL MORTALITY CURVES FOR CATEGORY 9 FROM HIROSHIMA SCALED BURST HEIGHTS

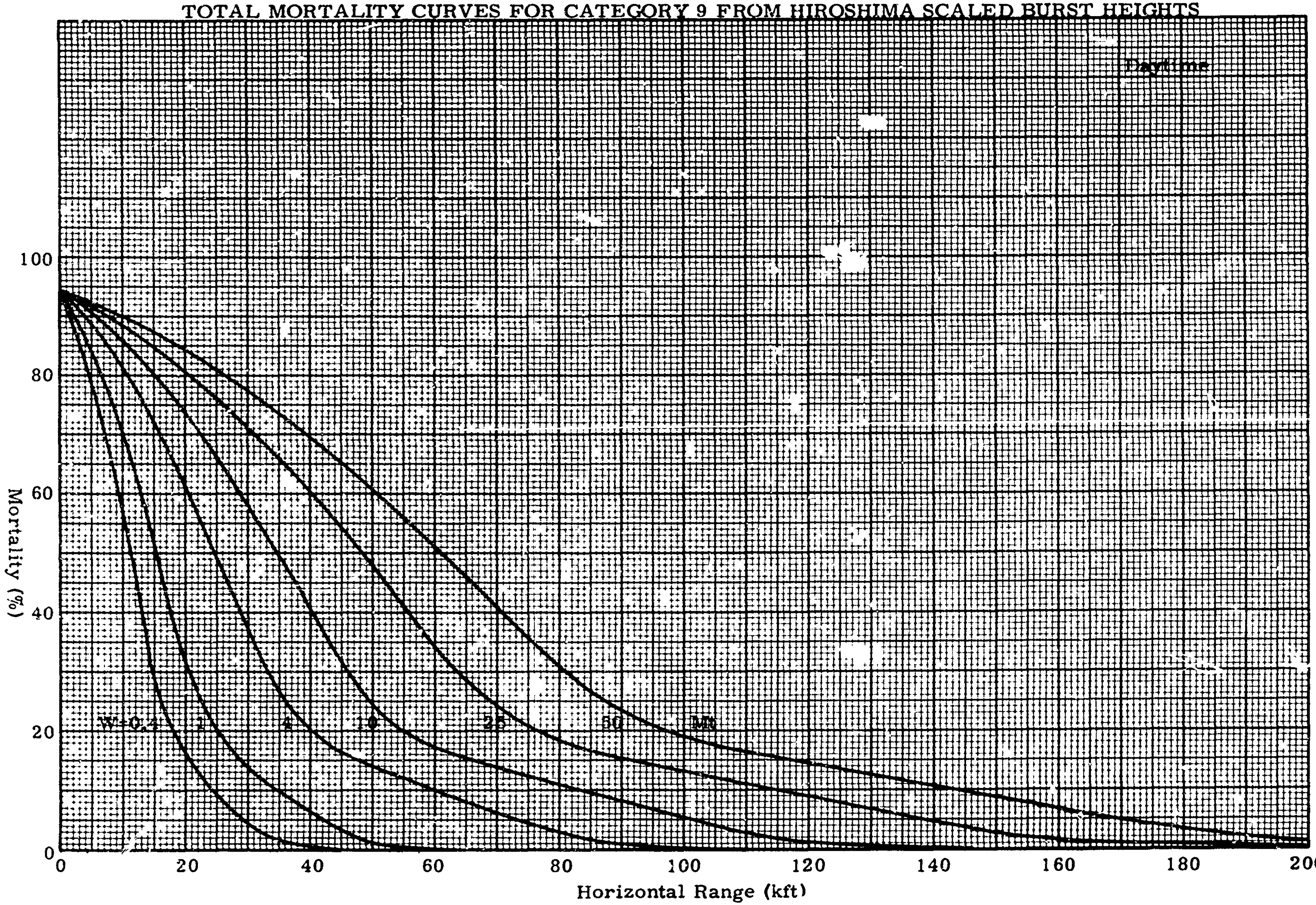


FIG. 50

TOTAL MORTALITY CURVES FOR CATEGORY 10 FROM HIROSHIMA SCALED BURST HEIGHTS

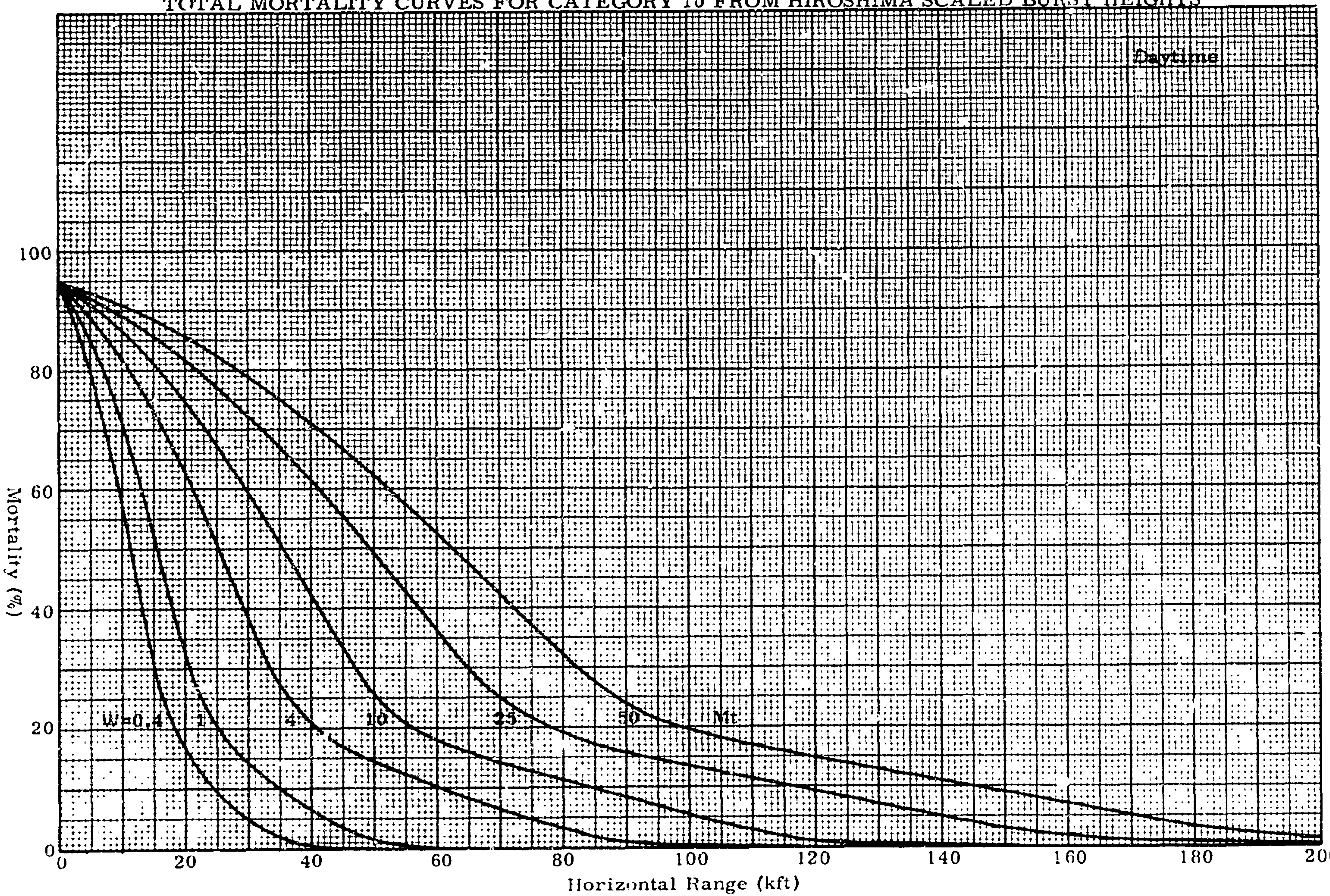


FIG. 51

TOTAL INJURY CURVES FOR CATEGORY 1 FROM HIROSHIMA SCALED BURST HEIGHTS

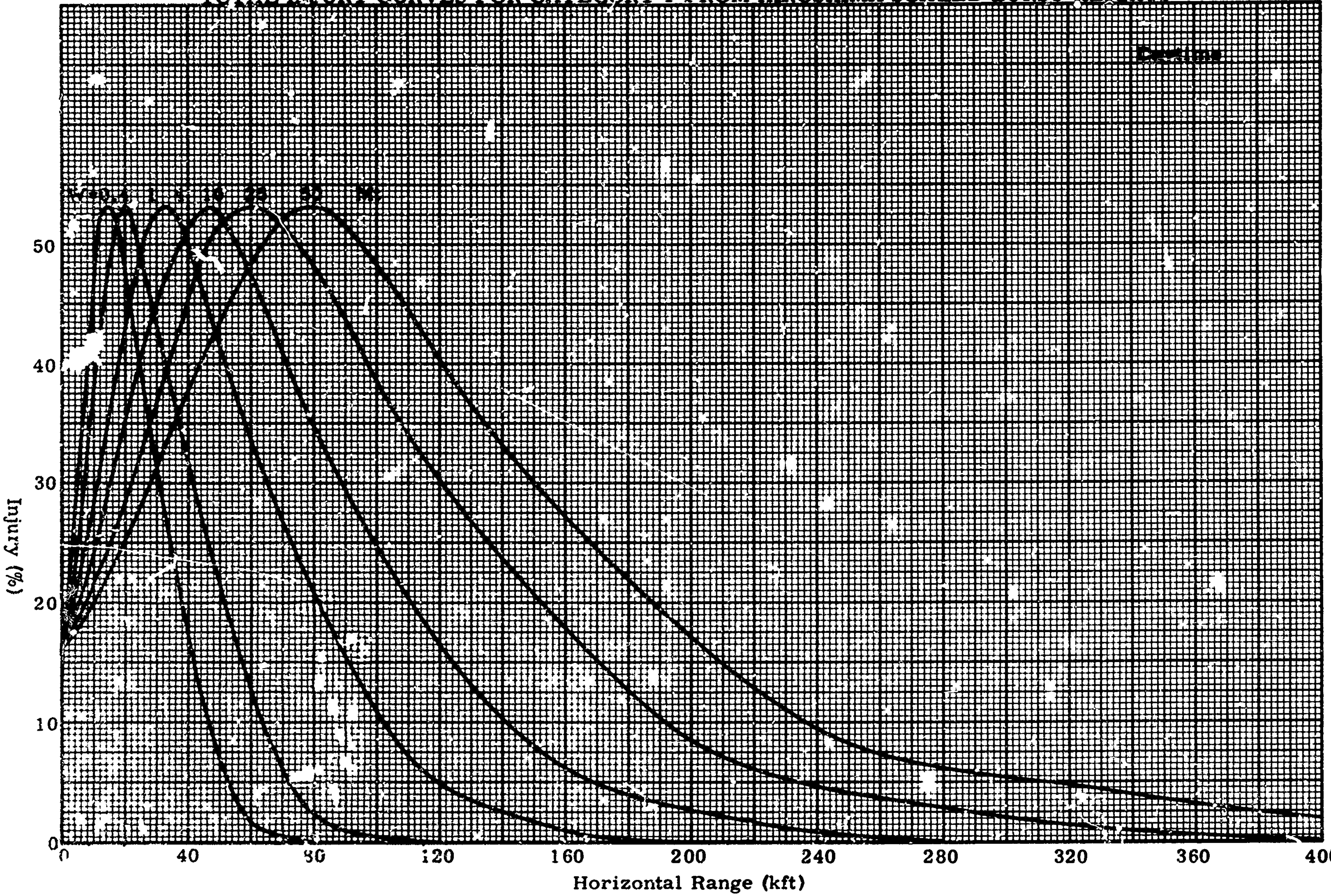


FIG. 52

.'OTAL INJURY CURVES FOR CATEGORIES 2 AND 5 FROM HIROSHIMA SCALED BURST HEIGHTS

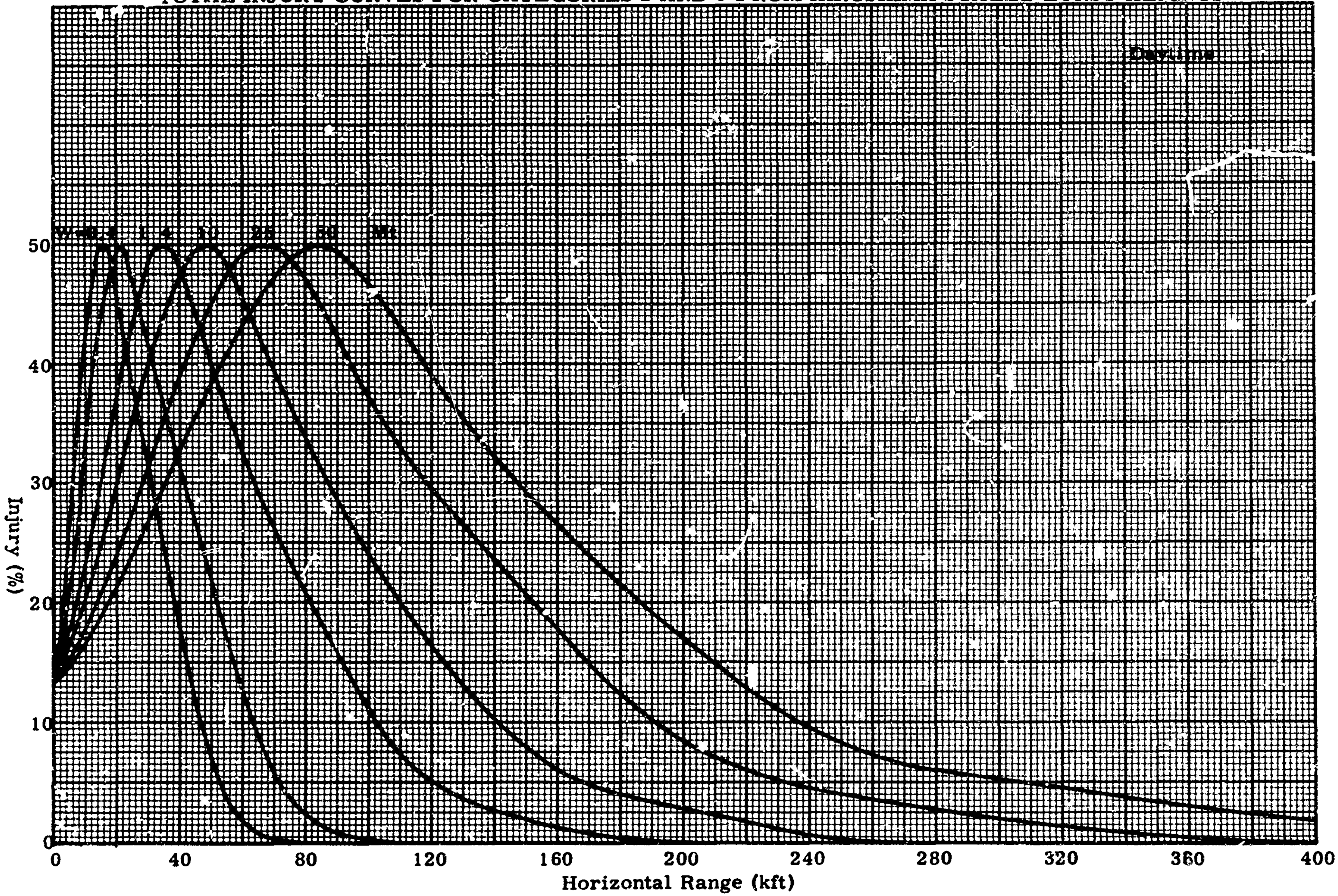


FIG. 53

TOTAL INJURY CURVES FOR CATEGORY 3 FROM HIROSHIMA SCALED BURST HEIGHTS

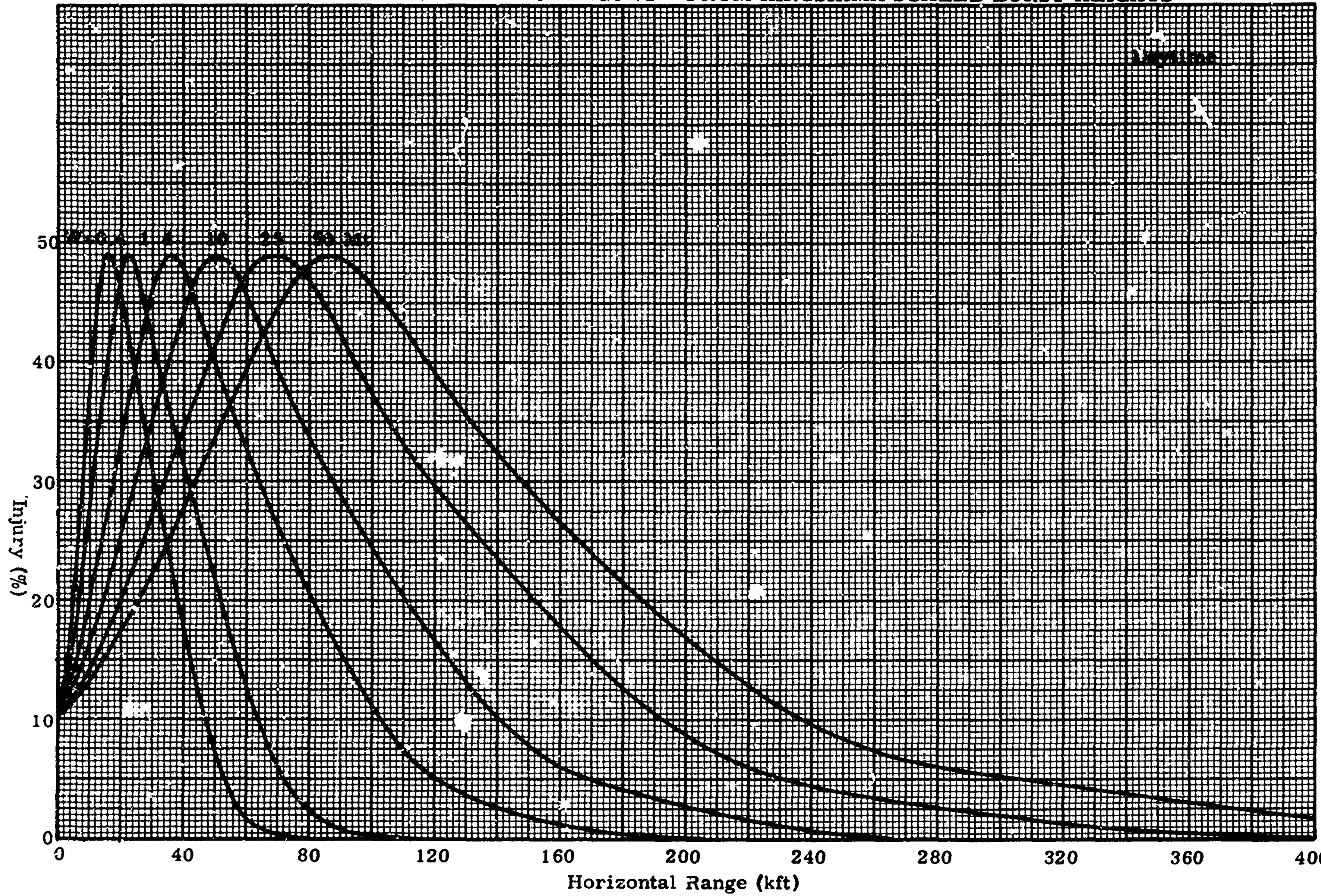


FIG. 54

TOTAL INJURY CURVES FOR CATEGORY 4 FROM HIROSHIMA SCALED BURST HEIGHTS

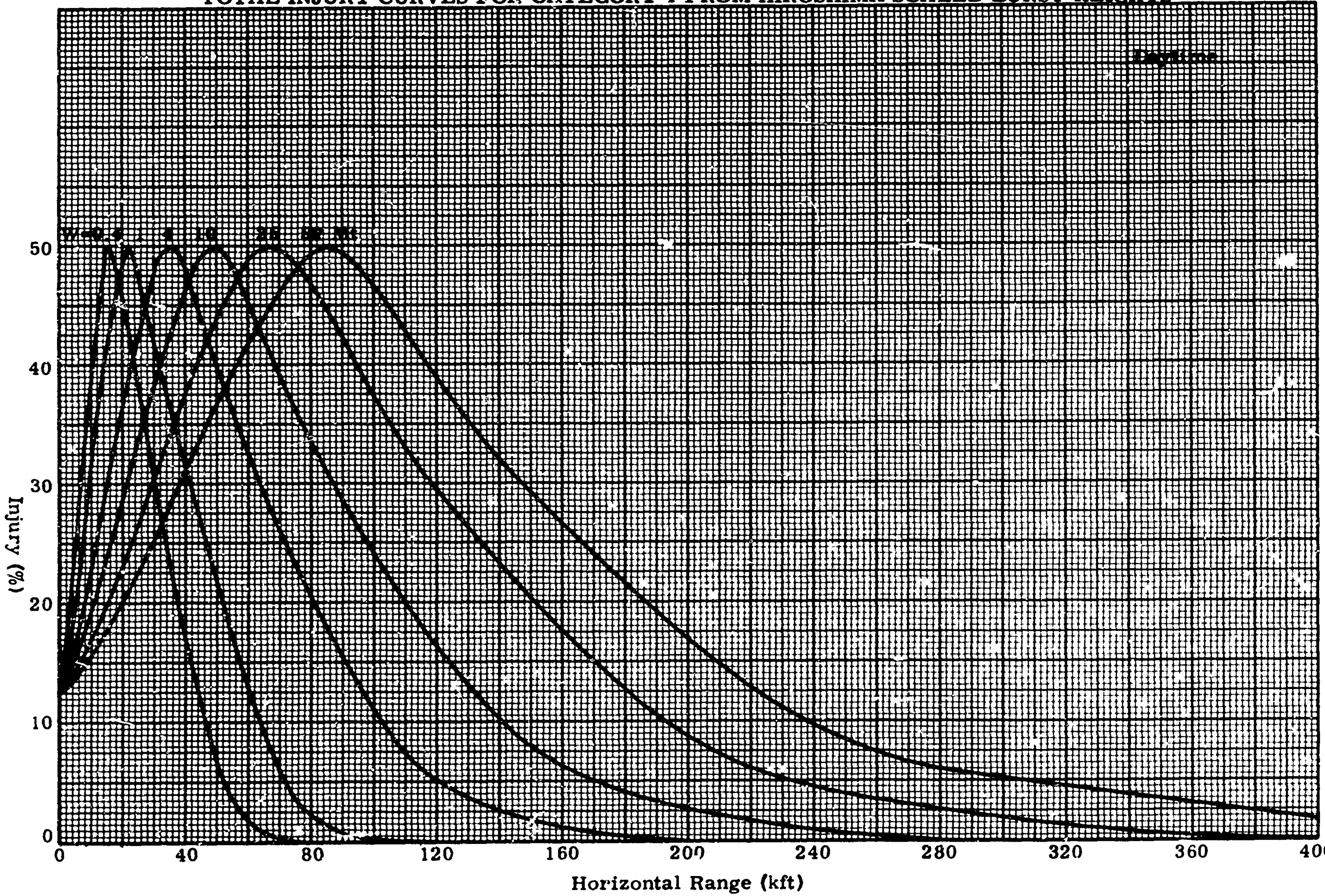


FIG. 55

TOTAL INJURY CURVES FOR CATEGORY 6 FROM HIROSHIMA SCALED BURST HEIGHTS

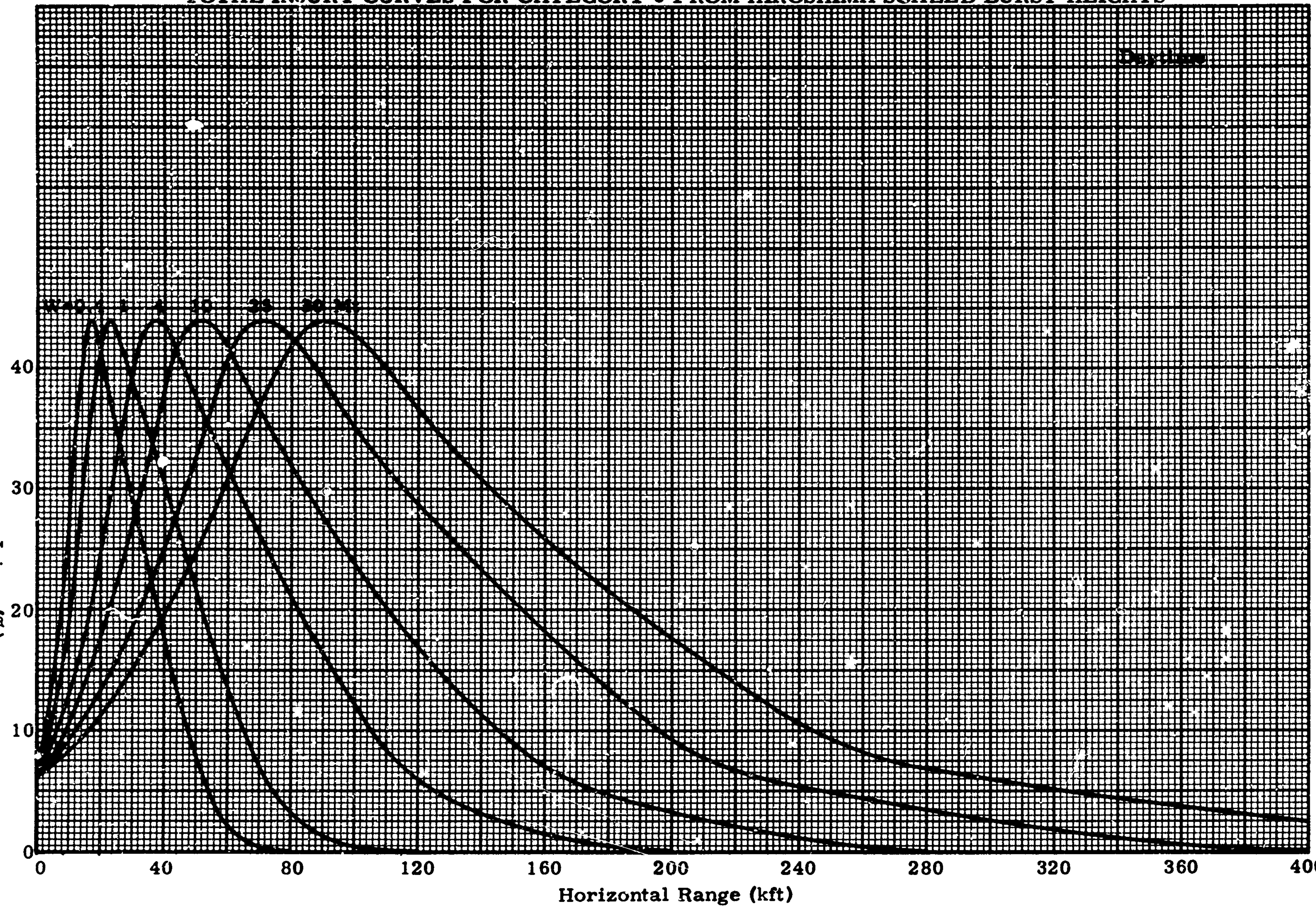


FIG. 56

TOTAL INJURY CURVES FOR CATEGORY 7 FROM HIROSHIMA SCALED BURST HEIGHTS

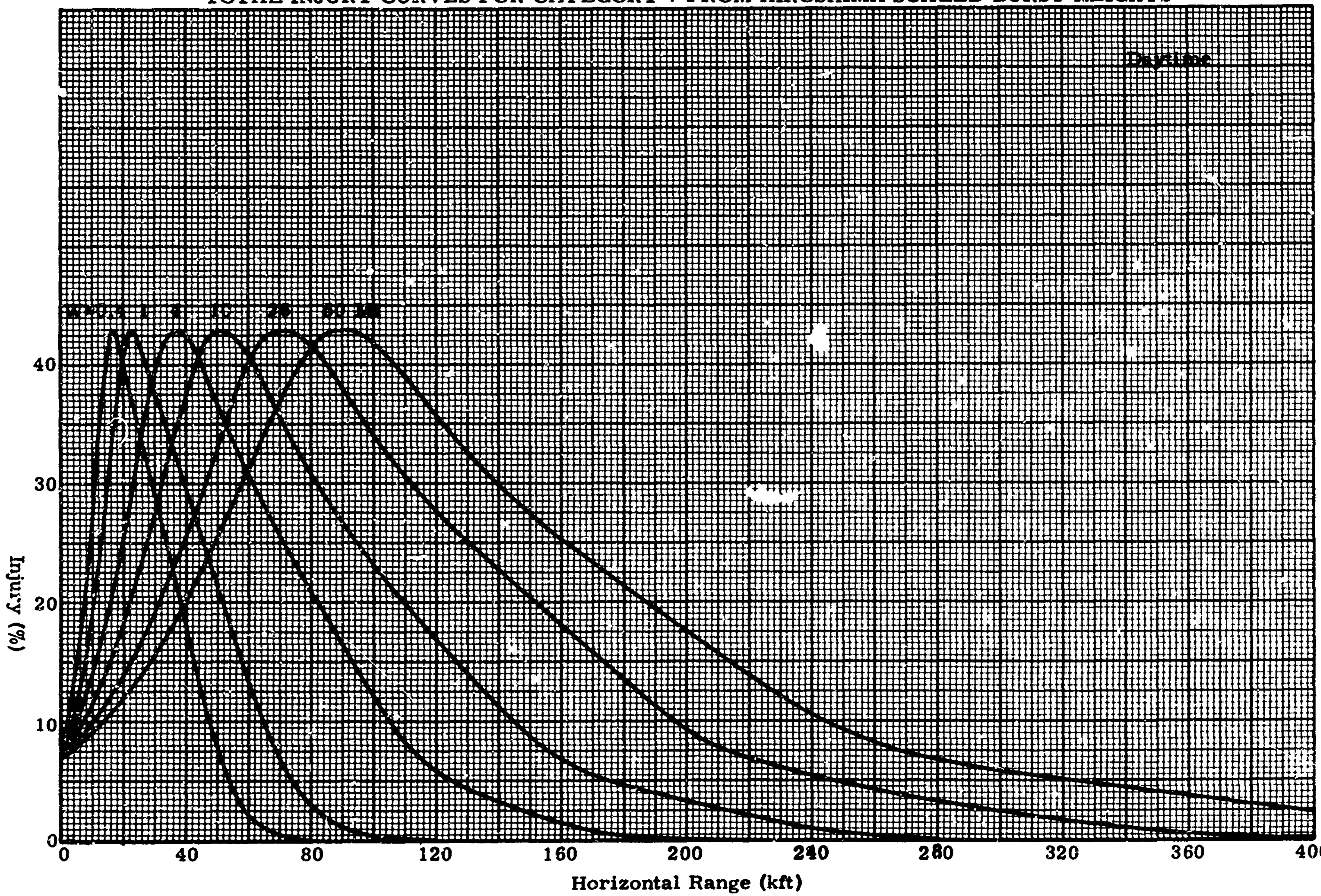


FIG. 57

TOTAL INJURY CURVES FOR CATEGORY 8 FROM HIROSHIMA SCALED BURST HEIGHTS

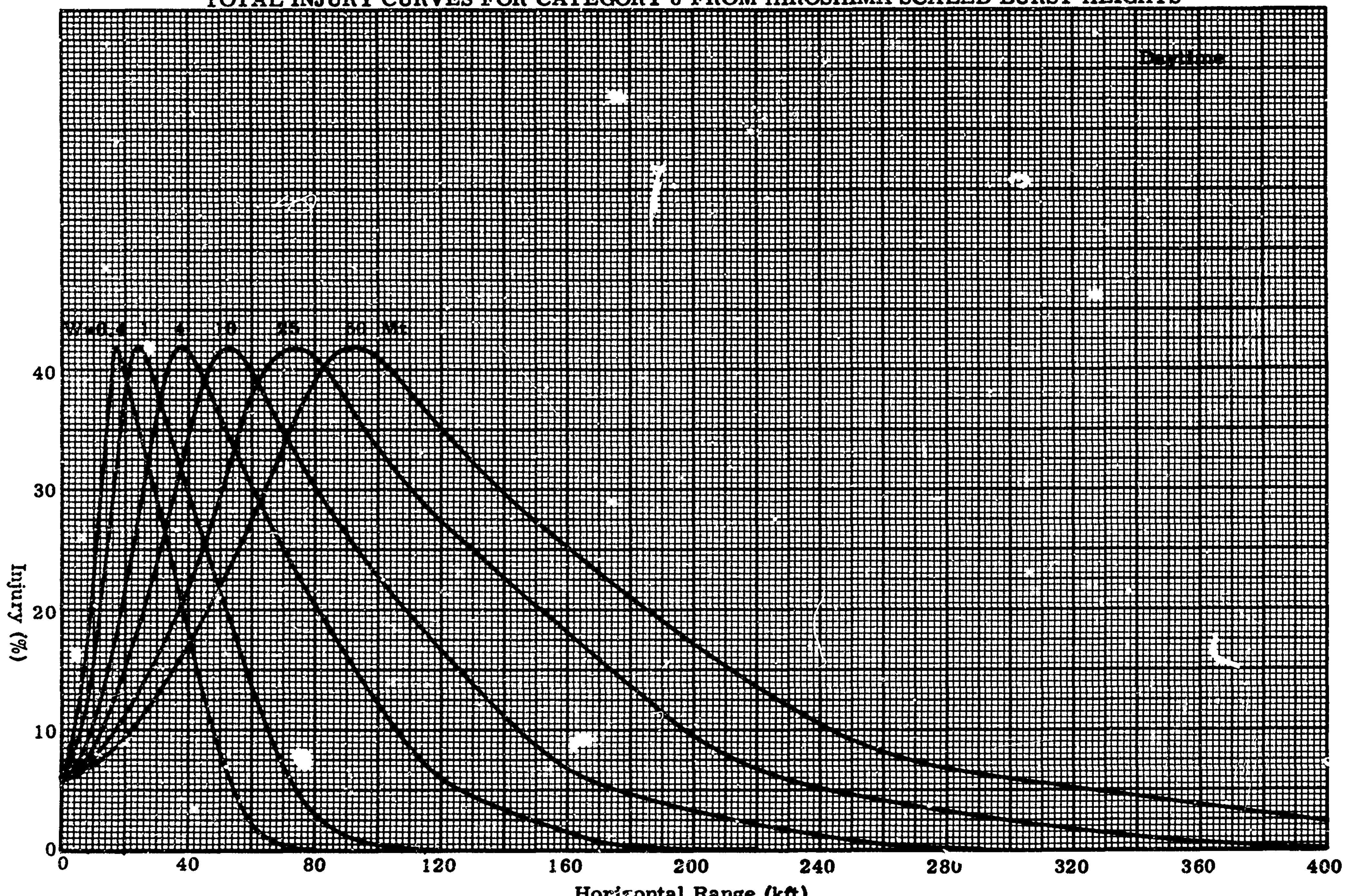


FIG. 58

TOTAL INJURY CURVES FOR CATEGORY 9 FROM HIROSHIMA SCALED BURST HEIGHTS

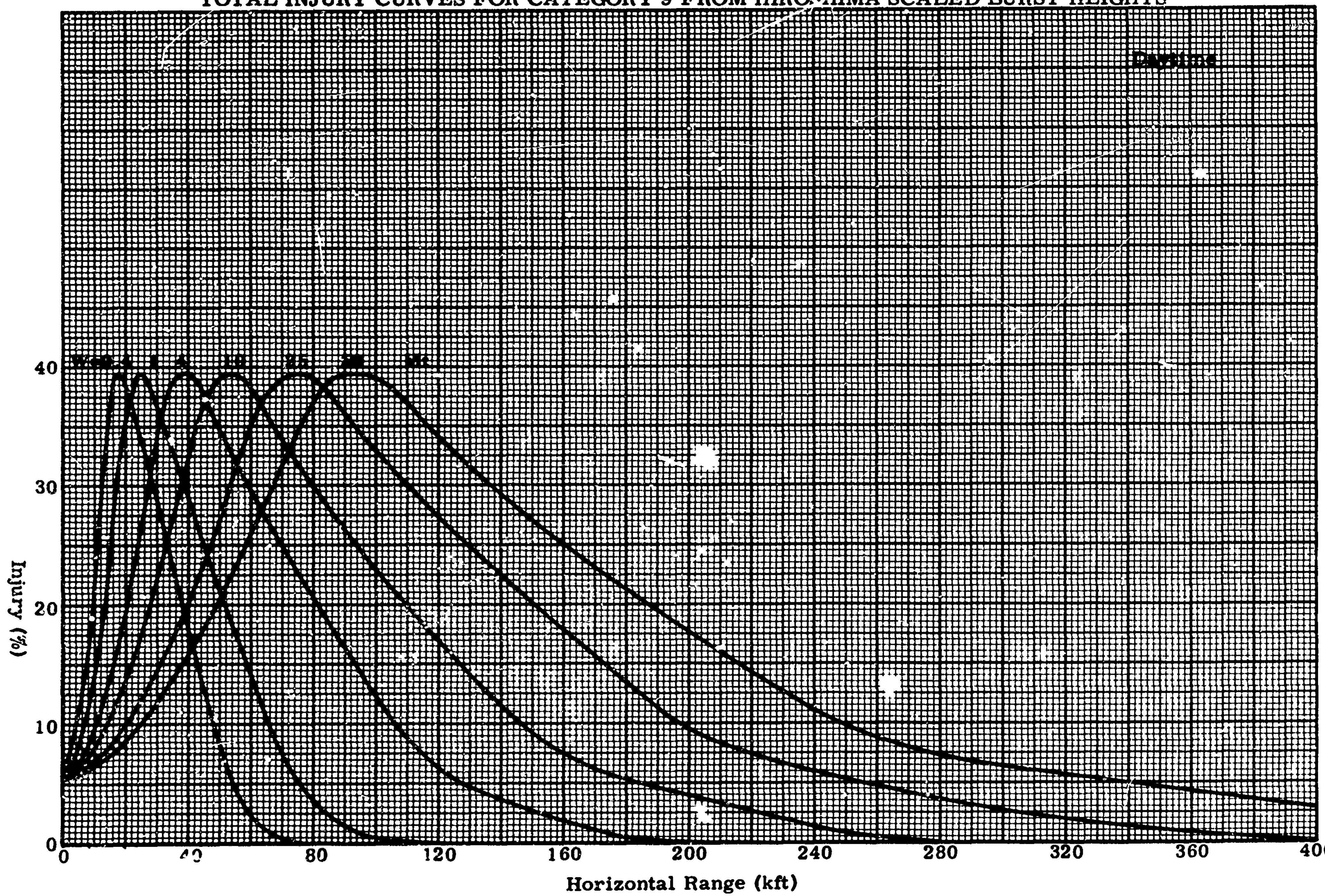


FIG. 59

TOTAL INJURY CURVES FOR CATEGORY 10 FROM HIROSHIMA SCALED BURST HEIGHTS

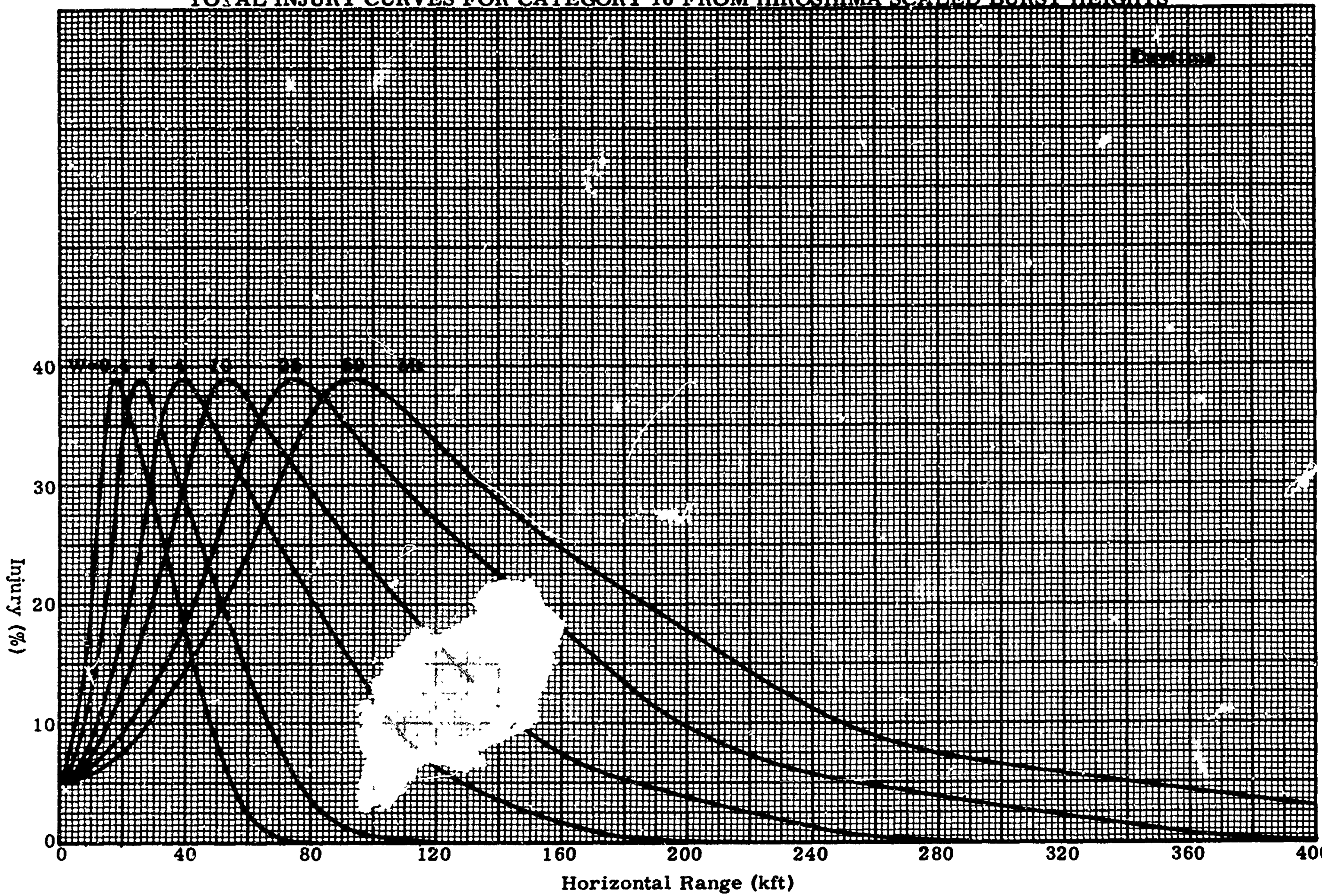


FIG. 60

TOTAL MORTALITY CURVES FOR A 10-MT SURFACE BURST

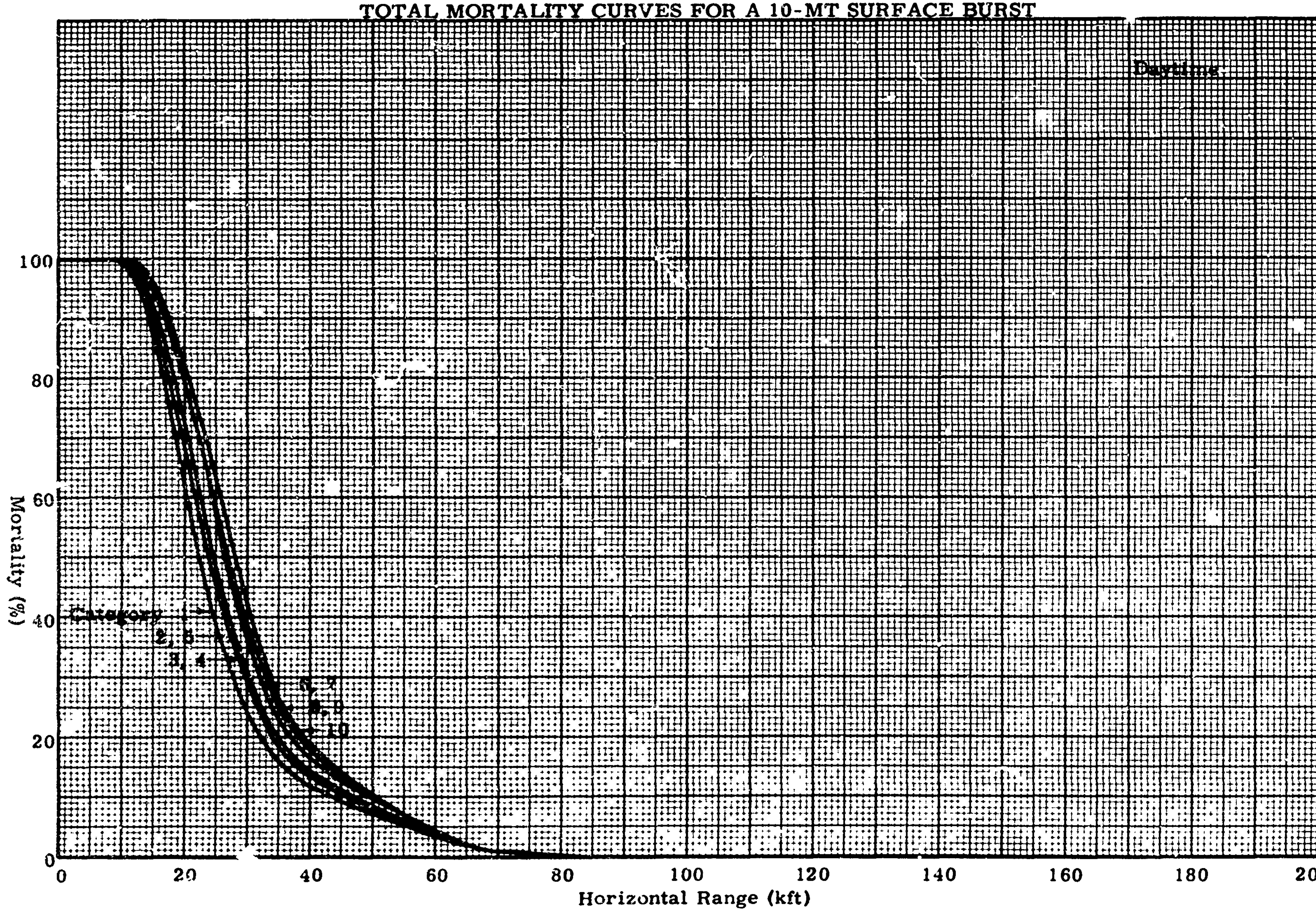
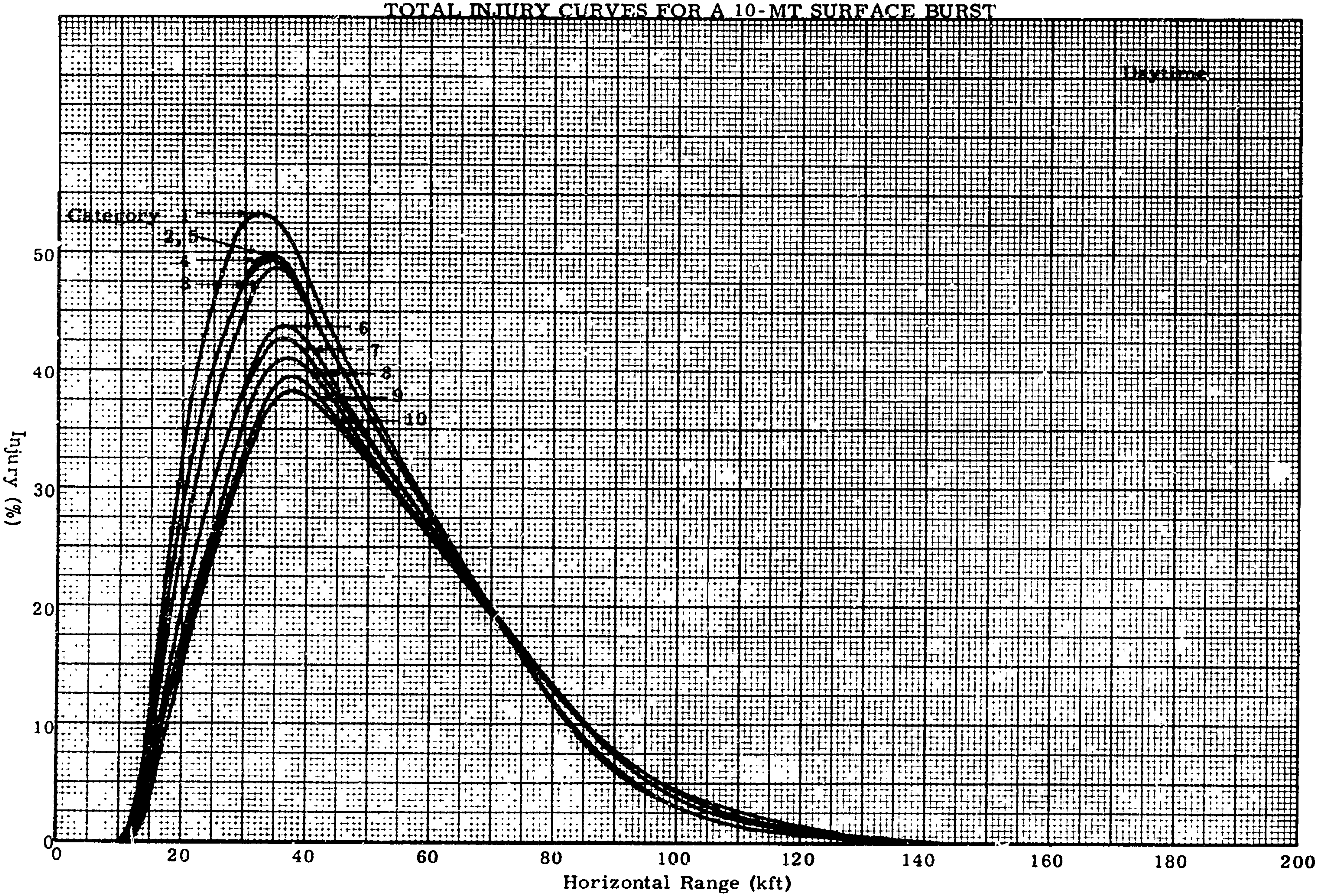


FIG. 61

TOTAL INJURY CURVES FOR A 10-MT SURFACE BURST



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3. W. A. Hamberg, et al., Study of Tactical Movement Concepts and Procedures for Civil Defense Planning, TR-210, Operations Research, Inc., August 31, 1963. (Unclassified)

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APPENDIX A

FORMAT OF BUILDING DATA TAPE

A. INTRODUCTION

The following is a brief description of the format and content of the building data tape. All of the data are recorded in binary form. The binary words are recorded in floating point (F), fixed point (I), and binary coded decimal or alphameric (A). They are so noted (F, I, A) in the following brief summary. The order of the words in a record are exactly the same as the following numerical listing. Each block of building data, including block heading data, is written as a single binary record on the tape. Blank (missing) data are recorded as a (-1.0) for all floating point data and as a binary-coded-decimal (BCD) blank for alphameric data.

B. DESCRIPTION OF BINARY RECORD ON TAPE

Note: Items 1 through 17 apply to the block and not specifically to the buildings within it:

(1) Sheet number (F) is a unique number assigned to a block. The sheet numbers run from 1 through 5289 sequentially. There are several sheet numbers which have the same integral value but differ in the hundredth position by one. An example is 45.00 and 45.01. The sheet number is a floating-point binary word and may consist of up to four digits to the left of the decimal and two to the right.

(2) City code (A) is the code assigned to a city. The codes run from 1 through 55 sequentially for the 55 cities processed. This code is a BCD binary word that may consist of up to two decimal digits. (The codes are given for each city in Table 15.)

(3) Sanborn volume (A) uses the volume code as read from the Sanborn map. The Sanborn volume is a BCD binary word that may consist of up to two decimal digits and one alphabetic character.

(4) Sanborn page (A) uses the page code as read from the Sanborn map. The Sanborn page is a BCD binary word that may consist of as many as four decimal digits plus one alphameric character.

(5) Sanborn block (A) uses the block code as read from the Sanborn map. The Sanborn block is a BCD binary word that may consist of as many as four alphameric characters.

(6) Area type or land use (A) uses the code assigned to the block which most adequately describes the use of the land. The area type is a BCD binary word that may consist of one decimal digit and one alphabetic character. (The codes are given for each land use in Table 5.)

(7) Area scale (F) is the scale of the Sanborn map. The area scale is a floating-point binary word that may be as large as 999.

(8) Upper street width (F) is the width (in feet) of the upper street bordering the block under consideration. This width is a floating-point binary word that may be as large as 999.

(9) Upper street length (F) is the length (in feet) of the upper street bordering the block under consideration. This length is a floating-point binary word that may be as large as 9999.

(10) Left street width (F) is the width (in feet) of the left street bordering the block being considered. This width is a floating-point binary word that can be as large as 999.

(11) Left street length (F) is the length (in feet) of the left street bordering the block under consideration. This length is a floating-point binary word that can be as large as 9999.

(12) Lower street width (F) is the width (in feet) of the lower street bordering the block being considered. This width is a floating-point binary word that may be as large as 999.

(13) Lower street length (F) is the length (in feet) of the lower street bordering the block under consideration. This length is a floating-point binary word that may be as large as 9999.

(14) Right street width (F) is the width (in feet) of the right street bordering the block in question. This width is a floating-point binary word that may be as large as 999.

(15) Right street length (F) is the length (in feet) of the right street bordering the block in question. This length is a floating-point binary word that may be as large as 9999.

(16) Block area (F) is the block area (in square feet) as read from the Sanborn map. This area is a floating-point binary word that may be as large as 399, 996, 000.

(17) Number of buildings (I) in the block is a fixed-point binary word giving the number of buildings in the block under consideration. (A unit of different height or construction is counted separately.)

> Note: The following information applies to each building within the block and is repeated in the binary record for each building:

(18) Number of floors (F) is the number of floors in the unit of the building for the block under consideration. This number is a floating-point binary word.

(19) Height of building (F) is the height (in feet) of the unit or building in question for the block being processed. This height is a floating-point binary word.

(20) Building ground area (F) is the ground area (in square feet) of the unit or building in question for the block being processed. This area is a floating-point binary word.

(21) Building use (A) utilizes the code assigned which most adequately describes the building's use. This code is a BCD binary word that may consist of five alphameric characters. (The codes are given for each building use in Table 7.)

(22) Building construction code one (A) is the first of three building construction codes that describe the building's construction. It is a BCD binary word that may consist of four alphameric characters. (The codes are given for each building construction in Table 8.)

(23) Building construction code two (A) is the second of three building construction codes that describe the building's construction, It is a BCD binary word that may consist of four alphameric characters.

(24) Building construction code three (A) is the third and last building construction code that describes the building's construction. It is a BCD binary word that may consist of four alphameric characters.

APPENDIX B

FORMAT OF BLOCK SUMMARY TAPE

A. INTRODUCTION

The coding system outlined for the building data tape will also be followed in this description. Thus, the binary word in the binary record for a block will have its mode indicated by (F) or (A) depending on whether it is floating or alphameric (binary-coded decimal), respectively. Missing or blank data will be recorded as a (-1.0) if the data word was to be in floating point and as a binary-coded-decimal (BCD) blank if it was to be alphameric. The numerical order of the binary block data words given below is the same as the words appear on the binary tape. (As on the building data tape, all data are written in binary form.) The summary for each block is written on the tape as a single binary record consisting of 36 binary data words (either floating point or alphameric).

B. DESCRIPTION OF BINARY RECORD ON TAPE

(1) Sheet number (F) is the same unique number assigned to the block as was given in the building summary. It is recorded as a floating-point binary number between 1 and 5289.

(2) City code (A) is the same applicable code assigned to the city in which the block is located as was given in the building summary. It is recorded as an alphameric (BCD) binary word consisting of up to two decimal digits.

(3) Sanborn volume (A) uses the same applicable code read from the Sanborn maps as in the building summary. It is recorded as an alphameric (BCD) binary word consisting of up to two decimal digits and one alphabetic character.

(4) Land use or area type (A) utilizes the same applicable code as in the building summary. It is recorded as an alphameric (BCD) binary word consisting of one decimal digit and one alphabetic character.

(5) Total building ground area (F) is the total ground area (in square feet) covered by buildings of the block in question. It is recorded as a floating-point binary word.

(6) Total block ground area (F) is the total ground area (in square feet) of the block under consideration, including one-half of the surrounding street area. It is recorded as a floating-point binary word.

(7) Total miscellaneous building area (F) is the total building area (in square feet) in the block which does not properly fall into one of the given building categories. (It is computed by multiplying the ground area of the building times the number of floors.) In this summary such special buildings as underground structures fall into the miscellaneous category. The total miscellaneous building area is recorded as a floating-point binary word.

(8) Total number of buildings (F) is the total number of buildings or units in the block. (Each unit of different construction or height is considered separately.) It is recorded as a floating-point binary word.

Note: The following binary data words apply to all buildings regardless of their particular construction category:

(9) Total floor area (not including basements) (F) is the total building floor area (in square feet) for all of the buildings in the block. (The floor area of a building is computed by multiplying the ground area of the building by the number of floors.) Basement floor area is not included in this total. The total floor area is recorded as a floating-point binary word.

(10) Total basement floor area (F) is the total basement floor area (in square feet) for all of the buildings in the block. It is recorded as a floating-point binary word.

(11) Total ground area of buildings over ten stories high (F) is the total ground area (in square feet) of buildings which exceed ten stories in height for the particular block. It is recorded as a floating-point binary word.

Note: The following binary data words apply to buildings of wood-frame construction:

(12) Total floor area (not including basements) (F) is the total floor area (in square feet) for wood-frame buildings in the block. (The building floor

area is computed by multiplying the building ground area by the number of floors.) The total floor area, which excludes any basements, is recorded as a floating-point binary word.

(13) <u>Total basement floor area</u> (F) is the total basement floor area (in square feet) for wood-frame buildings in the block under study. It is recorded as a floating-point binary word.

(14) <u>Total ground area of buildings over ten stories high</u> (F) is the total ground area (in square feet) for wood-frame buildings for those buildings which exceed ten stories in height. The total ground area is recorded as a floating-point binary word.

Note: The following binary data words apply to buildings of brick construction:

(15) <u>Total floor area (not including basements)</u> (F) is the total floor area (in square feet) for brick buildings in the block. (The floor area of a building is calculated by multiplying the number of floors by the ground area of the building.) The total floor area, which does not include basements, is recorded as a floating-point binary word.

(16) <u>Total basement floor area</u> (F) is the total basement floor area (in square feet) for brick buildings in the block. It is recorded as a floating-point binary word.

(17) Total ground area of buildings over ten stories high (F) is the total ground area (in square feet) of brick buildings which exceed ten stories in height for the block. It is recorded as a floating-point binary word.

Note: The following binary data words apply to buildings of American reinforced-concrete construction:

(18) Total floor area (not including basements) (F) is the total floor area (in square feet) for American reinforced-concrete buildings in the block. (The floor area of the building is calculated by multiplying the ground area by the number of floors in the building.) The total floor area, which does not include any basements, is recorded as a floating-point binary word.

(19) Total basement floor area (F) is the total basement floor area (in square feet) for American reinforced-concrete buildings in the block. It is recorded as a floating-point binary word.

(20) Total ground area of buildings over ten stories high (F) is the total ground area (in square feet) of American reinforced-concrete buildings which exceed ten stories in height for that block. The total ground area of buildings over ten stories high is recorded as a floating-point binary word.

Note: The following binary data words apply to buildings of Japanese reinforced-concrete construction:

(21) Total floor area (not including basements) (F) is the total floor area (in square feet) for Japanese reinforced-concrete buildings in the block.

(The floor area of a building is calculated by multiplying the number of floors in the building by the ground area.) The total floor area, which does not include any basements, is recorded as a floating-point binary word.

(22) Total basement floor area (F) is the total basement floor area (in square feet) for Japanese reinforced-concrete buildings in the block. It is recorded as a floating-point binary word.

(23) Total ground area of buildings over ten stories high (F) is the total ground area (in square feet) of Japanese reinforced-concrete buildings which exceed ten stories in height for that block. The total ground area for these buildings is recorded as a floating-point binary word.

> Note: The following binary data words apply to buildings of heavy-steel-frame construction. Also note that none of these buildings exceed ten stories in height because of the manner in which this construction category was defined:

(24) Total floor area (not including basements) (F) is the total floor area (in square feet) for heavy-steel-frame buildings in the block. (The floor area of a building is calculated by multiplying the number of floors by the building ground area.) The total floor area, which does not include any basements, is recorded as a floating-point binary word.

(25) Total basement floor area (F) is the total basement floor area (in square feet) for heavy-steel-frame buildings in the block. It is recorded as a floating-point binary word.

> Note: The following binary data words apply to buildings of light-steel-frame construction. Also note that none of these buildings exceed ten stories in height because of the manner in which this construction category was defined:

(26) Total floor area (not including basements) (F) is the total floor area (in square feet) for light-steel-frame buildings in the block. (Building floor area is calculated by multiplying the number of floors by its ground area.) The total floor area, which does not include any basements, is recorded as a floating-point binary word.

(27) Total basement floor area (F) is the total basement floor area (in square feet) for light-steel-frame buildings in the block. It is recorded as a floating-point binary word.

> Note: The following binary data words contain standard-location and census-data information for the block:

(28) Standard-location one (A) uses the first four alphameric characters of the standard-location tract in which the block is located. It is recorded as an alphameric (BCD) binary word.

(29) <u>Standard-location two</u> (A) uses the last four alphameric characters of the standard-location tract in which the block is located. It is recorded as an alphameric (BCD) binary word.

(30) <u>Census-tract one</u> (A) uses the first six alphameric characters of the census tract in which the block is located. It is recorded as an alphameric (BCD) binary word.

(31) <u>Census-tract two</u> (A) uses the last alphameric character of the census tract in which the block is located. It is recorded as an alphameric (BCD) binary word.

(32) <u>Census block</u> (A) uses the set of alphameric characters which the 1960 U. S. Census utilized to describe the block. It is recorded as an alphameric (BCD) binary word.

(33) <u>Block population</u> (F) is the population of the block as recorded by the 1960 U. S. Census. It is recorded as a floating-point binary word.

(34) <u>Standard-location residential population</u> (F) is the residential population, as recorded by the 1960 U. S. Census, of the standard-location tract in which the block is located. It is recorded as a floating-point binary word.

(35) <u>Standard-location day population</u> (F) is the daytime population of the standard-location tract in which the block is located. It is recorded as a floating-point binary word.

(36) Standard-location night population (F) is the nighttime population of the standard-location tract in which the block is located. It is recorded as a floating-point binary word.

APPENDIX C

MULTIVARIATE STATISTICAL ANALYSIS

A statistical model is a mathematical formulation, probabilistic in character, of the physical situation regarded as having generated an observed response. Thus, such a model in the development of typical urban areas expresses in logical quantitative form the effects of the three basic factors; namely, experimental errors, urban area size, and geographic region. The complete specifications of a model also include distributional stipulations as discussed below.

The observations, $y_1, y_2, \ldots,$ are subject to statistical fluctuations. As a consequence, they are termed observable random variables. Evidently, the observable variates depend upon such specific factors as geographic region and urban area size and upon such incidental random error factors as (1) the city blocks chosen, (2) the clerk assigned to do the reading, (3) the condition of the Sanborn map, etc.

In accordance with the definition of a statistical model given above, it is then clear that the model will specify a quantitative relationship between y and these factors. In particular, for the study of typical urban areas, a linear model was specified as follows:

$$y_{ijk} = \mu_k + R_{ik} + S_{jk} + e_{ijk} \tag{1}$$

$$i = 1, 2, \ldots, 11; \; j = 1, 2, 3; \; k = 1, 2, \ldots, 6$$

where,

y_{ijk} is the observation of the k^{th} construction type in the i^{th} region and j^{th} urban area size,

μ_k is a component common to all observations of the k^{th} construction type,

R_{ik} is a component of the k^{th} construction peculiar to the i^{th} geographic region,

S_{jk} is a component of the k^{th} construction peculiar to the j^{th} urban area size, and

e_{ijk} is the composite random error associated with y_{ijk} and due to the sources of random error discussed in the preceding paragraph.

It is assumed that

$$E\, e_{ijk} = 0$$

and

$$E\, e_{ijk}\, e_{ijk} = \sigma^2$$

For statistical completeness (to permit the solutions of the least squares equations), it is further assumed that

$$\sum_{i}^{11} R_{ik} = 0$$

and that

$$\sum_{j}^{3} S_{jk} = 0$$

To satisfy these restrictions, the R_{ik} and S_{jk} are redefined in the conventional way. Specifically, the observation equation for $y_{3,2,4}$ is defined as

$$y_{3,2,4} = \mu_4 + R_{3,4} + S_{2,4} + e_{3,2,4}$$

In the expanded form, representing all of the parameters of the least squares system pertinent to the fourth construction type, it is given as:

$$\begin{aligned} y_{3,2,4} &= \mu_4 + 0 \cdot R_{1,4} + 0 \cdot R_{2,4} + 1 \cdot R_{3,4} + 0 \cdot R_{4,4} + \cdots \\ &\quad + 0 \cdot R_{10,4} + 0 \cdot S_{1,4} + 1 \cdot S_{2,4} + e_{3,2,4} \end{aligned} \tag{2}$$

These definitions can be generalized for any $y_{i,j,k}$. In particular, the six equations for a single observation vector (i.e., representing the six construction types) can be written as:

$$\begin{aligned} y_{ij1} &= \mu_1 + R_{i1} + S_{j1} + e_{ij1} \\ y_{ij2} &= \mu_2 + R_{i2} + S_{j2} + e_{ij2} \\ &\vdots \\ y_{ij6} &= \mu_6 + R_{i6} + S_{j6} + e_{ij6} \end{aligned}$$

The non-random unknown variables, μ_k, R_{ik}, and S_{jk}, are generally termed experimental (as opposed to random) effects since they are

the quantitative but unknown results of the assignable factors--the geographic regions and urban area sizes.

The equations representing the observations can be put into the more concise matrix notation as follows:

$$Y = A\theta + e \tag{3}$$

where,

- Y is an $n \times 6$ matrix of the observations, each element in a six-element row representing one construction type for a particular observation,
- θ is a 13×6 matrix of the unknown experimental effects in the observation equation,
- A is an $n \times 13$ matrix of 0's and 1's such that the 1's in the ij^{th} row correspond to the effects of the θ matrix associated with the observations y_{ijk}, and
- e is an $n \times 6$ matrix of the unobservable random errors.

By way of additional explanation concerning the A matrix, note that the 0 and 1 coefficients in Eq. (2) above exactly form the 3, 2^{th} row of matrix A.

The least squares procedure may now be used to obtain a solution of the system in Eq. (3) such that $e'e$ is minimized with respect to θ. Hence,

$$e'e = (Y - A\theta)'(Y - A\theta)$$

$$\frac{de'e}{d\theta} = (Y - A\theta)'(-A) + (-A')(Y - A\theta)$$
$$= (-A')(Y - A\theta) + (-A')(Y - A\theta)$$
$$= -2A'Y + 2A'A\theta$$

Setting this expression equal to zero, the resulting normal equations are

$$A'A\hat{\theta} = A'Y$$

$\hat{\theta}$ is used to indicate estimates instead of the exact parameters, which remain unknown (though estimated). The least squares solution is then

$$\hat{\theta} = (A'A)^{-1} A'Y \tag{4}$$

For the problem of assessing the significance of geographic region and urban area size on construction, one is interested in the reduction of the experimental error under the hypothesis implied by the statistical model in Eq. (1). To study this reduction, the error* or deviation about regression is used as follows:

$$\text{ERROR} = Y'Y - Y'A\hat{\theta} \tag{5}$$

$Y'Y$ is analogous to the total sum of the squares in univariate statistical analysis, and $Y'A\hat{\theta}$ is analogous to the reduction in this sum due to regression, it being tacitly assumed that the introduction of the regression variable will reduce the error variance.

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*The word "error" is understood to be error in the statistical sense, or residual variation about the multivariate regression equation. It is analogous to standard deviation in non-regression problems.

The object of the multivariate analysis procedure applicable to this particular problem is to compare this reduction with the reduction that can be achieved under several alternate hypotheses. For this particular problem, the hypotheses of interest are that geographic region has no effect on construction and that urban area size has no effect on construction. Equations similar to Eq. (1) for these reduced hypotheses are:

$$y_{jk} = \mu_k + S_{jk} + e_{jk} \tag{6}$$

and

$$y_{ik} = \mu_k + R_{ik} + e_{ik} \tag{7}$$

Of course, modifications must obviously be made in the definitions. The error reduction assuming the complete hypothesis, given by Eq. (1), is compared with the reduction assuming each of these reduced hypotheses. If the reduction assuming the complete hypothesis is not significantly greater than the reduction assuming a reduced hypothesis, then the factor by which the hypotheses differ is not statistically significant as an explanation for any of the variability observed in the data set.

The comparison in reduction is made by examining the change in error (i.e., Eq. (5)) for the complete and the reduced hypotheses. It is of interest to note that this error is often called the residual since it is the remainder of the total variability after that variability which can be assigned to the non-random factors of the model has been removed. The

multivariate statistic that has been developed for this type of problem is as follows:

$$U = \frac{\text{det (residual assuming the complete model)}}{\text{det (residual assuming the reduced model)}} \tag{8}$$

In this equation det (residual assuming, etc.) is the determinate of Eq. (5) for the particular model involved. If this observed U is not sufficiently less than one, the factor by which the models, or hypotheses, differ is not significant as an explanation of data variability.

This statistic was computed for each reduced hypothesis for all land uses and for several combinations of land uses. Theoretical values against which these computed statistics must be compared have never been extensively tabled. In fact, none of the tables required for this project existed; thus, as the analysis proceeded, isolated theoretical values had to be estimated. All of the results and the corresponding statistical conclusions have been discussed in Chapter VI. For a more extensive treatment of the multivariate problem, the reader is referred to Chapter 8 of An Introduction to Multivariate Statistical Analysis (Ref. 5).